E09772

COAL TAR

AND SOME OF ITS PRODUCTS

PITMAN'S COMMON COMMODITIES AND INDUSTRIES SERIES

Each book in crown 8vo, illustrated, 3/- net

Acids, Alkalis, and Salts. By G H J Adlam
Alcohol. By C Simmonds
Aluminium. By G Mortimer
Anthracite. By A L Summers
Asbestos. By A L Summers
Bookbinding Craft and Industry, The. By T Harrison
Books: From the MS. to the Bookseller. By J L Young
Boot and Shoe Industry, The. By J S Harding
Bread and Bread Baking. By J Stewart
Brushmaker, The. By W Kiddier
Butter and Cheese. By C W W Tisdale and J Jones
Button Industry, The. By W U Jones
Carpets. By S Brinton
Clays. By B Searle
Clocks and Watches. By G L Overton
Clothing Industry, The. By B W Poole
Cloths and the Cloth Trade. By J A Hunter
Coal. By H Wilson
Coal Tar. By A R Warnes
Coffee. By B B Keable
Cold Storage and Ice-making. By B H Springett
Concrete and Reinforced Concrete. By W N Twelvetrees
Copper. By H K Picard
Cordage and Cordage Hemp and Fibres. By T Woodhouse and P Kilgour
Corn Trade, The British. By A Barker
Cotton. By R J Peake
Cotton Spinning. By A S Wade
Cycle Industry, The. By W Grew
Drugs in Commerce. By J Humphrey
Dyes By A J Hall
Electric Lamp Industry, The. By G A Percival
Electricity By R E Neale
Engraving. By T W Lascelles
Explosives, Modern. By S I Levy
Fertilizers. By H Cave
Film Industry, The. By D Boughey
Fishing Industry. By W E Gibbs
Furniture. By A E Binstead
Furs and the Fur Trade. By J C Sachs
Gas and Gas Making. By W H Y Webber
Glass and Glass Making. By P Marson
Gloves and the Glove Trade. By B E Ellis
Gold. By B White
Gums and Resins. By E J Parry
Incandescent Lighting. By S I Levy
Ink. By C A Mitchell
Internal Combustion Engines. By J Okill
Iron and Steel. By C Hood
Ironfounding. By B Whiteley
Jute Industry, The. By T Woodhouse and P Kilgour
Knitted Fabrics. By J Chamberlain and J H Quilter
Lead. By J A Smythe
Leather. By K J Adcock
Linen. By S Moore
Locks and Lockmaking. By F J Butter
Match Industry, The. By W Dixon
Meat Industry, The. By W Wood
Motor Industry, The. By H Wyatt
Nickel. By B H White
Oil Power. By S H North
Oils. By C A Mitchell
Paints and Varnishes. By A S Jennings
Paper. By H A Maddox
Patent Fuels. By J A Greene and M Perkin
Perfumery. By E J Parry
Photography. By W Gamble
Piano Player, The. By D M Wilson
Platinum Metals. By E A Smith
Pottery. By C J Noke and H J Plant
Rice. By C E Douglas
Rubber. By H P and W H Stevens
Salt. By A F Calvert
Shipbuilding and the Shipbuilding Industry. By J Mitchell
Silk. By L Hooper
Silver. By B White
Soap. By W H Simmons
Sponges. By E J J Cresswell
Starch and Starch Products. By H A Auden
Stones and Quarries. By J A Howe
Straw Hats. By H Inwards
Sugar. By the late G Martineau Revised by F C Eastick
Sulphur and Allied Products. By H A Auden
Talking Machines. By O Mitchell
Tea. By A Ibbetson
Telegraphy, Telephony, and Wireless. By J Poole
Textile Bleaching. By A B Steven
Timber. By W Bullock
Tin and the Tin Industry. By A H Mundey
Tobacco. By A E Tanner
Velvet and the Corduroy Industry. By J H Cooke
Wall Paper. By G W Ward
Weaving. By W P Crankshaw
Wheat. By A Miller
Wine and the Wine Trade. By A Simon
Wool. By J A Hunter
Worsted Industry, The. By J Dumville and S Kershaw
Zinc. By T E Lones

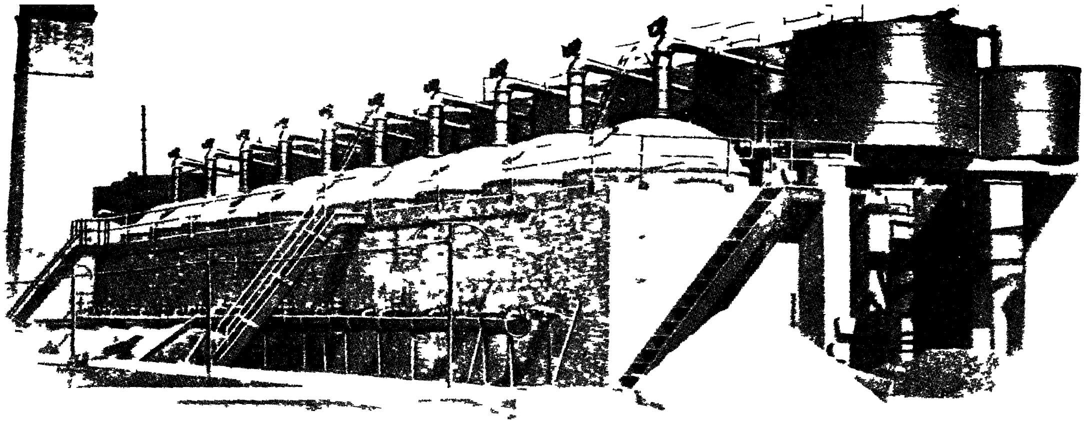

FIG. 1

BATTERY OF TAR STILLS (INTERMITTENT SYSTEM)

(1468B)

PITMAN'S COMMON COMMODITIES
AND INDUSTRIES

COAL TAR

AND SOME OF ITS PRODUCTS

BY

ARTHUR R. WARNES
F.I.C., A.INST.P., M.I.CHEM.E., A.I.STRUCT.E.
MEMBER FARADAY SOCIETY, ETC.,
LATE LECTURER ON "COAL TAR DISTILLATION" AT
HULL TECHNICAL COLLEGE

SECOND EDITION

LONDON
SIR ISAAC PITMAN & SONS, LTD.
PARKER STREET, KINGSWAY, W.C.2
BATH, MELBOURNE, TORONTO, NEW YORK

PRINTED IN GREAT BRITAIN
AT THE PITMAN PRESS, BATH

PREFACE

TO THE SECOND EDITION

This book has been carefully revised and brought up to date so far as it is possible with a small work of this kind. Whilst in the Coal Tar industry many improvements have been made in the details of both plant and processes which are very technical, the general principles as laid down in this book remain the same.

ARTHUR R. WARNES.

LONDON.

PREFACE

THE object of this little book is to place before non-technical readers a brief account of the origin and uses of Coal Tar, and of the methods employed to obtain from it materials of considerable importance to a very large number of industries. It has been the endeavour of the writer to explain very technical processes in a manner understandable by those who have not made a special study of chemical technology. The task has not been an easy one, but he hopes that his efforts have at least come within the bounds of success.

That the business man and the student of commerce should have some idea of the scientific side of the many industries of the world has been proved "up to the hilt" since the outbreak of the present war, and if this little book has successfully contributed its quota towards this end then the writer and the publishers have been amply rewarded for their labours.

The importance of the Coal Tar industry to this country in times of peace was very great indeed. Its value during the present war is of the highest, one might almost say paramount, as will be seen clearly by the reader after he has carefully perused the pages of this work.

The writer wishes to acknowledge his indebtedness to the following firms for the loan of the blocks, drawings, and photographs from which the illustrations in this book have been prepared. Messrs. R. & J. Dempster, Ltd., of Manchester; The Leeds and Bradford Boiler Co., Ltd., of Stanningley, nr. Leeds; Messrs. W. J. Fraser & Co., of Dagenham; Messrs. W. C. Holmes & Co., Ltd., of Huddersfield; Messrs. Pott, Cassel & Williamson, of Motherwell; and the Premier Filterpress Co., Ltd., of London.

ARTHUR R. WARNES.

HULL.

CONTENTS

CHAP. PAGE

PREFACE v

INTRODUCTION ix

I. COAL TAR AND ITS MANUFACTURE; PREPARED TAR; TAR FOR ROOFING FELT; YIELD OF DISTILLATES FROM TAR . . 1

II. DESTRUCTIVE DISTILLATION OF COAL TAR . 9

III. PITCH AND ITS USES; CREOSOTE OIL AND ITS USES; NAPHTHALENE AND ITS USES; ANTHRACENE OIL 23

IV. AMMONIACAL LIQUOR AND THE MANUFACTURE OF SOME COMPOUNDS OF AMMONIA . 39

V. WORKING UP OF CRUDE NAPHTHA AND LIGHT OIL 48

VI. CHEMICAL TREATMENT OF ONCE-RUN BENZOL, ONCE-RUN NAPHTHA AND ONCE-RUN HEAVY NAPHTHA 60

VII. MANUFACTURE OF BENZOLS AND NAPHTHAS 65

VIII. MANUFACTURE OF COMMERCIALLY PURE BENZENE AND TOLUENE AND SOME OF THEIR USES 75

IX. MANUFACTURE OF PYRIDINE BASES . . 81

X. MANUFACTURE OF CARBOLIC AND CRESYLIC ACIDS AND SOME OF THEIR USES . . 86

BIBLIOGRAPHY 102

INDEX 104

LIST OF ILLUSTRATIONS

FIG. PAGE
1. BATTERY OF TAR STILLS (INTERMITTENT SYSTEM) *Frontispiece*
2. TAR STILL (LYING ON ITS SIDE) 11
3. BATTERY OF TAR STILLS (INTERMITTENT SYSTEM). 13
4. STILL (SURROUNDED BY BRICKWORK), AND CONDENSER AND COIL (SHOWN IN SECTION) . . 15
5. HIRD'S CONTINUOUS TAR DISTILLATION PLANT . 19
6. CENTRIFUGAL MACHINE 29
7. CENTRIFUGAL MACHINE 31
8. CENTRIFUGAL MACHINE (SECTION) . . . 33
9. IRON FILTER PRESS 34
10. FILTER PRESS WITH WOODEN PLATES AND FRAMES 35
11. SULPHATE OF AMMONIA PLANT 41
12. SULPHATE OF AMMONIA PLANT (ELEVATION) . 43
13. SULPHATE OF AMMONIA PLANT (PLAN) . . 45
14. PRIMARY FRACTIONATING STILL. . . . 51
15. FINAL FRACTIONATING STILL 67
16. FAMILY TREE (BENZENE AND SOME OF ITS DERIVATIVES) . . . . . . *facing* 78
17. FAMILY TREE (PHENOL AND SOME OF ITS DERIVATIVES) . . . . . . *facing* 98

INTRODUCTION

It has been said that all our wealth springs from the land, and so far as coal tar is concerned this saying is, in the main, correct. The source of coal tar is, as its name implies, coal, and coal is a sedimentary rock formed of mineralized vegetation which, before it can be used, has to be dug from the earth. It appears that digging or mining for coal was not commenced in England until about the middle of the thirteenth century when, in the year 1259, King Henry III granted a charter to the freemen of Newcastle-on-Tyne to carry out this operation. In the year 1307 coal was not only mined in Northumberland but in Shropshire and Staffordshire, but its use for manufacturing purposes, at least in the London area, was prohibited by a royal proclamation made in the same year.

Towards the beginning of the seventeenth century the need for a better supply of fuel began to make itself felt, and this led to a great increase in the operation of mining coal, particularly in the county of Northumberland. Now, as the pits got deeper, it became more expensive to work them, and also difficulties were encountered in the shape of water, and this necessitated scientific thought to be given to the matter. This application of scientific thought resulted in the invention by Capt. Thomas Savery, in the year 1698, of a steam-engine which, when attached to a pump, cleared the pit of water far quicker than by hand. Seven years later a Dartmouth blacksmith, Newcomen, built an engine of somewhat crude design and construction which superseded Savery's engine, and was used for many years as a pumping engine for coal mines. It should be also mentioned that the steam-engine provided a more efficient means of raising coal from the pits. Some time later James Watt, after being brought into contact with Newcomen's engine, applied scientific thought and skill to the improvement of the steam-engine, and in the year 1769 he patented an engine, which brought him not only fame, but great financial reward.

Watt eventually became a partner of Matthew Boulton, of Soho, Birmingham, and it was at the works of Boulton & Watt that the first coal gas plant made its appearance. It was on account of the skill of William Murdoch, an engineer at Boulton & Watt's works, that the manufacture of gas from coal became possible. Here it was then that coal tar made its appearance in any quantity, and curiously enough the engineers who made it possible to mine coal more economically than heretofore were also responsible for the erection of the coal gas plant, and hence the first supply of coal gas with its by-product, coal tar.

As a matter of historical interest it should be mentioned in this place that in Goethe's episodes from his life he describes a visit, in the year 1741, to what he called the burning hill, a spot near the village of Dutweiler, in the Palatinate. Here he met a peculiar man of the name of Stauf, whom he christened a coal philosopher, and found him carrying on the process of destructive distillation of coal in a very crude form of coke oven and collecting the oils, resin, and tar given off.

We have now arrived at the period when coal tar first made its appearance; in form a thick black, more or less greasy, liquid possessing an unpleasant smell and considered by those who made it as a useless and troublesome article. As gas-making increased so did the production of this unsightly and apparently worthless material, and it became evident to those who produced it that some attempt would have to be made to find a means by which to dispose of it. Here again scientific thought had to be brought to bear upon the problem, this time, however, not by the engineer but by the chemist. To the chemists of the later part of the eighteenth century and the earlier part of the nineteenth century, with their very limited knowledge and also the small amount and crudeness of the apparatus at their disposal, an investigation of this nature must have appeared a very formidable one; a far more difficult one than that which the merchants of the same period had to face when they tackled the ways and means of selling articles of commerce at a profit to themselves under the inconvenience of poor means of transit, both by land and water, the Berlin Decree of Napoleon (November, 1806) and the war with the United States of America (1812–1814), etc.

At the period under consideration the foundations of organic chemistry were being laid, and by the great majority the chemist was thought to be more of a crank than a useful citizen. Time has, however, proved this to be otherwise. Very little was done in the matter of investigating the nature of coal tar until the year 1820, when Garden isolated the white, beautifully crystalline substance, naphthalene, from it. Further progress was made by Runge, who carried out a considerable amount of investigatory work on coal tar, and who, in 1834, obtained from it *phenol (carbolic acid), aniline (in very small quantity), quinoline, and* pyrol. While conducting his experimental work he also obtained two compounds one of which he called rosolic acid (aurine) and the other brunolic acid. Later investigators could not confirm the presence of these compounds in coal tar and it is thought that they were produced from some of the constituents of the tar by some of the methods used by him in his experiments.

During the next year (1833) Dumas and Laurent, whilst working upon coal tar, discovered anthracene, or paranaphthalene as it was then called, and four years later (1837) Laurent found chrysene and pyrene, which discoveries were followed by Anderson discovering picoline in coal tar in 1846. In the year previous to this (1845) A. W. Hofmann proved the presence of benzene in coal tar, twenty years after its discovery by Faraday in portable gas, and three years later (1848), at the Royal College of Chemistry, Hofmann induced one of his brilliant students, Charles Blachford Mansfield, to make a systematic study of coal tar, which Hofmann called "one of the most wonderful productions in the whole range of chemistry." The truth of this saying will become evident to the reader after he has perused the pages of this little work. Curiously enough the distillation of coal tar was conducted on a fairly large scale at a works in the neighbourhood of Manchester as early as 1834, eleven years before Hofmann's discovery of benzene in coal tar naphtha, and black varnish was prepared from the naphtha and pitch resulting from the distillation. Also in the year 1842 a quantity of benzene was exhibited to the British Association at their meeting in Manchester, by John Leigh. The report on this procedure was apparently so obscure that it is uncertain whether the benzene was obtained from coal tar, and Hofmann, so it seems, was unacquainted with it.

Mansfield did much valuable work on coal tar and showed that practically an unlimited supply (at his time, but not now) of benzene might be obtained from it. He worked also on the first distillate from coal tar *i.e.*, coal tar naphtha, and in addition to obtaining from it benzene in a pure state, isolated almost pure toluene, some pseudocumene, and was lead to suspect the presence of xylene. Taking into consideration the crude apparatus and laboratory furnishings which were at Mansfield's disposal it is wonderful how accurate his work turned out to be, and chemists of the present day cannot but admire the perseverance and skilful technique which he displayed under these very adverse conditions. When he brought the results of his work before the Chemical Society of London in 1849, in the form of a paper he very modestly said: "It has been perhaps the tedium of the methods necessary to effect a separation of mixed hydrocarbons from each other which has deterred experienced chemists from devoting their time to disentangling the oils here treated of: and perhaps to have conducted the innumerable distillations necessary for this purpose in a laboratory imperfectly furnished with gas and other conveniences, would have been a task too laborious to have been persisted in."

It should be mentioned, in passing, that in the year 1847 Mansfield patented a process for the manufacture of nitrobenzene from benzene.

We have now arrived at the period (1856) when W. H. Perkin discovered the first coal tar colour which he called mauve. This discovery is considered as the foundation of the coal tar colour industry, and it was certainly responsible for the stimulation of research and technical work upon coal tar. Perkin (afterwards Sir W. H. Perkin) made the discovery during the Easter vacation of 1856, at the early age of 18 years, in a rough laboratory which he had fitted up in the house of his father. To quote the words of the late Dr. F. M. Perkin, F.I.C.,[1] one of the late Sir W. H. Perkin's sons: "As a matter of fact, the actual discovery of the dye was an accident. The aim which my father had in view was the synthesis of quinine. With our present knowledge we know that it would not be possible to synthesize quinine simply by the oxidation of aniline, but in those days, when organic chemistry was in its infancy, the assumption appeared quite probable. In 1856 it seemed quite legitimate to assume that a natural product might be synthesized if the elements composing it could be brought together in the right proportions."

"Now, although the actual discovery of the dye was an accident, it required a mind of particular aptitude to work up a dirty black substance, to extract the dye, and afterwards to carry out the laborious work which was necessary to prove that it was a dye and could be used in place of dyes obtained from natural products. I wish to lay stress on this, because the average person—the 'man in the street'—is apt to think the discovery of the substance is the main point. It is really not the discovery of a new substance which is the chief thing, for thousands of substances have been put on one side as useless until the inventive mind came along and opened out new branches of industry."

What Dr. F. M. Perkin remarked in this last sentence can also be said of coal tar, which, as has already been stated, was considered as a worthless material, in fact, a nuisance, in the earlier days of its production.

After Perkin discovered mauve he was persuaded of the importance of it as a colouring matter, and this resulted in his interviewing his master, Hofmann, in the October of the same year as he made his discovery. To cite words used by Perkin himself in his famous Hofmann memorial lecture given in the year 1896 before the Society of Chemical Industry: ". . . I sought an interview with my old master, Hofmann, and told him of the discovery of this dye, showing him patterns dyed with it, at the same time saying that as I was going to undertake its manufacture, I was sorry that I should have to leave the Royal College of Chemistry. At this he appeared much annoyed and spoke in a very discouraging manner, making me feel that perhaps I might be taking a false step which might ruin my future prospects. I have sometimes thought that, appreciating the difficulties of producing such compounds as aniline and this colouring matter on the large scale, Hofmann perhaps anticipated that the undertaking would be a failure, and was sorry to think that I should be so foolish as to leave my scientific work for such an object, especially as I was then but a lad of 18 years of age; and I must confess that one of my great fears on entering into technical work was that it might prevent my continuing research work, but I determined that, as far as possible, this should not be the case."

---

[1] *Journal of the Society of Dyers and Colourists*, 10th November, 1914, page 339.

Perkin did not discontinue his research work and he made many brilliant discoveries before his death, resulting in the founding of industries for which the technical and commercial world have much cause to honour his memory.

He commenced to manufacture mauve towards the end of the year 1857 at the (now famous) Greenford Green Works, and this created such a demand for coal tar benzene that the tar distillers of that day could not meet it. Also the benzene they supplied was of a very irregular quality containing impurities which had to be removed by fractional distillation; a process much more difficult then than it is to-day. This demand added great stimulus to the coal tar industry, and chemists and constructional engineers set to work to find out processes and to construct more suitable plant in order to enable the tar distiller to turn out larger quantities of a better quality benzene. It is interesting to note that Perkin's first supply of benzene came from the tar distillery of Messrs. Miller & Co., of Glasgow.

The attention of the reader should be drawn to the fact that Perkin's discovery of mauve not only originated the coal tar colour industry, which now holds such a prominent position in the industrial world, but it was the cause of manufacturers of nitric acid looking into the matter of improving their existing methods in order to produce a much stronger acid. The acid then made was not strong enough for Perkin's use and he, with his great resourcefulness, had to devise a means of nitrating his benzene by using a mixture of sulphuric acid and nitrate of soda.

Manufacturers of chemical plant had to depend upon the technical side of their establishments to improve existing plants and to design new ones in order to cope with the demand.

Another interesting point in connection with the discovery of the first coal tar colour should be brought before the notice of the reader. It is best given in Perkin's own words: "On the Continent manufacturers do not appear to have succeeded well in manufacturing nitrobenzol when it first became a commercial article; their difficulty appears to have arisen from the fact that they experimented in earthenware vessels, which are both dangerous and unsuitable, and it was not until information was obtained from

England, I believe, that they were able to produce this body at a moderate price."

The discovery of cyanine or quinoline blue by Greville Williams, in 1856, the same year as that in which Perkin discovered mauve, must not be overlooked. Cyanine is a coal tar colour which was found to dye silk a beautiful blue shade, but unfortunately in practice it proved too fugitive. However, the matter did not end here, for cyanine was found to be the first representative of a group of colouring matters of great importance as special sensitizers for photographic purposes. Cyanine is prepared from quinone, and quinone from aniline. Hydroquinone is another member of this series and this material is prepared from quinone, which, as has already been stated, is made from aniline. Aniline is manufactured from benzene, and as will be remembered, benzene is obtained from coal tar. Thus it will be seen that Greville Williams was really the originator of, and coal tar the source of, another vast industry, viz.: the manufacture of synthetic photographic chemicals. Greville Williams was for some time a chemist at Perkin's Greenford Green Works.

Whilst Perkin was going through his training at the Royal College of Chemistry Hofmann set him to research on the hydrocarbon anthracene. Anthracene is a coal tar product, and Perkin was instructed to obtain his anthracene from pitch by subjecting it (the pitch) to distillation. This method of preparation proved to be a difficult one to carry out in the chemical laboratory, and so Hofmann obtained some crude anthracene from Bethel's Tar Works. The object which Hofmann had in mind was not realized by Perkin's work, and the research was discontinued, but the experience which Perkin gained was of great assistance to him some years later when he commenced to investigate the methods of manufacture of alizarin.

Between 1848 and 1862 a good deal of investigatory work was carried out upon coal tar, and at a discourse given by Hofmann, at the Royal Institution in 1862, he pointed out that Mansfield, in 1848, issued a list of thirteen compounds which had been isolated from coal tar, and since that time up to the date of his (Hofmann's) discourse twenty-seven more had been discovered.

Perkin's investigations on the production of alizarin were started in the year 1868 when Graebe and Lieberman in Germany discovered that alizarin, the colouring matter of the madder plant, was a derivative of the coal tar hydrocarbon anthracene, and that it could be prepared from this compound. It should be noted, in passing, that the work of Graebe and Liebermann placed on record the accomplishment of the first laboratory synthesis of a natural colouring matter.

The first process which the German discoverers patented was found to be too costly to enter into competition with the colouring matter produced from the madder plant, and Perkin at once realized the great importance of devising a cheaper process and immediately undertook researches with this object in view. His work in this connection resulted, in the year 1869, in the discovery of two methods for the manufacture of artificial alizarin, and he commenced to produce it commercially at his Greenford Green Works in the same year, producing 1 ton. It is interesting to note here that Perkin's works turned out 40 tons of artificial alizarin (in paste form) in 1870 and 220 tons in 1871, while it was not produced on the Continent until 1871 when 125 to 150 tons were made.

With the production of synthetic alizarin on the manufacturing scale and in increasing quantities came the demand for raw materials. One of these, the coal tar hydrocarbon anthracene, had to be obtained at Perkin's works by distilling pitch, but this process was rather an expensive one and the anthracene produced contained impurities which were difficult to remove, so another source of supply was sought. It was known that the last distillate collected off coal tar (green oil) contained crude anthracene, and tar distillers were asked to try and separate this material from their distillates. The greater number of the tar distillers in the United Kingdom were visited and details given them in regard to the best method to adopt to produce crude anthracene. In a short period large quantities were received at the Greenford Green Works and the distillation of pitch was abandoned.

The matter was not yet ended, as the crude anthracene had to be purified, and this meant more pioneering work for Perkin and his staff.

The fact that the discovery of a manufacturing process to produce synthetic alizarin stimulated progress in the caustic soda and the sulphuric acid industries must not be overlooked.

From this period more rapid progress was made in the coal tar distillation industry. Chemists set to work to improve the methods of distilling tar and of extracting from the distillates valuable compounds, and with the assistance of the plant engineer (now called the chemical engineer) improvements were made in connection with existing plant and plants of new designs were constructed. The horizontal type of tar still was largely replaced by the vertical or pot still; better types of washers were erected for the process of extracting tar acids from the distillates, and for washing the crude benzols and naphthas. More suitable fractionating stills were designed which enabled the tar distiller to manufacture purer benzols and naphthas, and from these commercially pure products, and plant for the recovery of naphthalene and anthracene were improved from time to time.

For many years the valuable coal tar product, carbolic acid or phenol, was allowed to remain in the coal tar distillates in which it occurred, but Messrs. Lowe & Crace Calvert, of Manchester, both Englishmen, began to look into this matter and originated methods of extracting not only carbolic acid (phenol), but the other phenols from the coal tar oils. In 1872 Lowe patented a process for the recovery of carbolic acid from heavy coal tar oils. It should be noted that these two Englishmen were the pioneers in the production of commercially and chemically pure carbolic acid.

A method by which the caustic soda used in the recovery of phenols is saved and the loss of phenols reduced, was investigated by Josiah Hardman, who in the year 1885 took out a patent for a process in which carbonic acid gas was used instead of sulphuric acid. He erected a plant at his works near Stoke-on-Trent, the working of which proved a success, and this process is still being used at the same works to-day, but in a much improved form. As will be seen by the reader in Chapter X, the CO_2 process, as it is now called, is employed very largely in tar distilleries at the present time.

The first coal tar distillery was erected at Leith in the year 1822; thus the coal tar distilling industry is, at the time of revising (1930), 108 years old. From this industry, thirty-four years after its origin, and owing to Perkin's discovery, sprung the coal tar colour industry which, during the period between its birth (1856) and 1890, attained to a considerable state of development. It also added impetus to the development of the tar distilling industry, which at the present day is in a satisfactory condition. Unfortunately, this latter remark cannot be applied to the state of the coal tar colour industry, which, since about the year 1890, has been on the decline in this country. It should be noted that the late European war has tended to alter this state of affairs somewhat, and it is to be hoped that the improvements which are now taking place will continue.

The reasons for the decline just mentioned are many, and they have suffered much discussion at the hands of scientists and others. There is no doubt that the lack of encouragement of the application of scientific thought and investigation to manufacturing processes by commercial men is one of the chief causes; business men, owing to the fact that in the majority of cases during their early education they have not been taught how useful a servant science is to industry, have failed to realize its value as applied to their own businesses, and this undoubtedly casts the onus of blame upon the system of education practised in this country. Professor Arthur G. Green, F.I.C., F.C.S., in a paper read before the British Association at a meeting held in Glasgow in 1901, said: "It is not so much the education of our chemists which is at fault as the scientific education of the public as a whole."

The coal tar colour industry is one requiring the assistance of chemists possessing a very high degree of training in chemistry for its successful maintenance and progress. In the coal tar industry at present such highly trained chemists are not usually employed, but it would be far better for the industry if a larger number of the more highly trained men were employed in it and research work carried out to a greater extent than it is at the moment. There is undoubtedly a very considerable amount of material yet remaining in coal tar which is not utilized, and if support is given by business men and financiers to scientific investigation then there is a great future in that direction. We in Great Britain distil more than one-half of the tar produced in Europe. Let us then reap the benefits of our labours to the full by utilizing the united efforts of science and commerce!

COAL TAR

CHAPTER I

In the manufacture of coal gas, coal is filled into vessels which, according to the manner in which they are arranged, are termed horizontal, inclined or vertical retorts. These vessels are strongly heated from the outside, and the high temperature to which they are exposed decomposes the coal inside into coal gas, coal tar, ammoniacal water and coke. The latter remains in the retorts whilst the three former substances are led away into a trough-shaped pipe called the hydraulic main. The gas passes along to the holders via the condensers, the washers or scrubbers and the purifiers, whilst the greater part of the substance which it is intended to deal with in this volume, coal tar, and also the ammonia water, deposits in the hydraulic main. From here they are carried away by separate lines of pipe to their respective storage tanks. The storage tank for the tar is known technically as the " Tar Well," and the tar remains in this tank until it is disposed of to the tar distiller.

The amount of tar obtained from a ton of coal varies approximately between ten and twelve gallons when the coal is submitted to " high temperature " carbonization, and between twelve and seventeen and one-half gallons in the case of " low temperature " carbonization.

The tar is removed from the tar well by means of a pump, and in the majority of cases is delivered into railway tank wagons, lighters or carts. In some instances, however, it is pumped direct from the gas works to the tar distillery through a large cast-iron pipe, the length of which is often over a mile. Whichever method is employed to convey the tar to the distillery, on its arrival there it is pumped into large storage tanks which, in some works, hold nearly one million gallons. These tanks are constructed of iron or steel plates, or of brick or reinforced concrete, and they are erected above or below ground, according to circumstances or the ideas of the management. The tar is allowed to remain in these tanks until the excess of ammonia water has risen to the surface, and, as there are, or should be, two or more storage tanks in a tar distillery, the tar can be pumped from one of them into vessels called tar stills, whilst that in the remainder is settling.

The manufacture of coal gas was commenced in the year 1798 at the works of Messrs. Boulton & Watt, Soho, Birmingham, the gas being used for private consumption. About fifteen years later, a public gas works was erected in London, and from this time works for the manufacture of gas sprung up all over the country. The two by-products resulting from the manufacture of gas—ammoniacal liquor and coal tar—were, however, considered as troublesome materials, and in many cases their presence became a veritable "nightmare" to the gas works proprietors, and considerable expense was incurred in their removal from the works.

As gas making increased it became very clear that something would have to be done to cope with the larger volume of coal tar and ammoniacal liquor which resulted, and many attempts were made to find a use for coal tar, but with very little success. About forty years after the first gas works was erected, an Englishman (Bethell) discovered that one of the oils obtained from coal tar, by recovering the liquids which came off when it was heated in a closed vessel, was an excellent material for the preservation of timber. This discovery stimulated further work in this direction on account of the fact that, in the building of railways, large quantities of wood "sleepers" are required for tying the railway metals together, and, as these rot very rapidly and so become a source of danger and expense unless they are preserved in some way, anything which would minimize these troubles was greatly welcomed. As time went on the heating of tar in closed vessels provided with a small outlet, and the collecting and condensing of the vapours given off (tar distilling), was given a good deal of attention, and larger quantities than heretofore were submitted to this process. Many valuable products, other than the oil in question, which came from the tar were not, however, employed to any great extent, and they were often thrown away.

In the year 1825 M. Faraday discovered benzene in the liquid deposited on compressing gas obtained from oil, and in 1845 Dr. Hofmann, while in England, pointed out its existence in coal tar. Later, C. B. Mansfield, under Hofmann's direction, prepared large quantities of benzene and did a considerable amount of work on this material. Unfortunately Mansfield was very seriously burned on the 17th February, 1856, while distilling benzene, and this resulted in his death. During the same year Perkin, then a youth of 18, discovered the first aniline colour, which he called mauve, while experimenting with aniline, a substance obtained from benzene. This discovery added further stimulus to the coal tar distillation industry, and it has now grown into one of the most important in the world. To the tar distiller the practice of coking coal in coke ovens is another source of supply of coal tar, and it is yearly becoming a more valuable one. By-product coke ovens were introduced into England in the year 1869, but it was not until about 1886 that the recovery of coal tar, etc., from the coal carbonized in them received the serious attention which it deserved. Modern coke ovens can be considered for all practical purposes as large retorts, and the chief object of carbonizing coal in installations of these ovens is to manufacture coke of a suitable nature for use in blast furnaces and foundry cupolas. Washed slack, or fine coal, is charged into the ovens and the gas, coal tar and ammoniacal liquor driven off on heating are dealt with in a very similar manner to that used in a gas works.

Coal tar is an almost black oily liquid which varies in its viscidity (flowing property), specific gravity (weight as compared with the weight of a similar volume of water) and composition, according to the type of retort in which the coal was carbonized, or to the temperature (that is to say, whether the temperature employed was very high or comparatively low), or to the variety of coal carbonized.

Some coals yield a tar containing a large quantity of the white body known as naphthalene (albo-carbon), and less of the valuable substances benzol and toluol, whilst other coals yield a tar containing less naphthalene and more benzol and toluol, and others a tar containing a high percentage of bodies similar to those which occur in paraffin oil (called technically paraffinoid hydrocarbons). Coal carbonized at a high temperature yields a tar which contains a considerable amount of naphthalene and also comparatively large quantities of benzol and toluol, whilst those tars obtained from coal carbonized at comparatively low temperatures contain less of the substances just mentioned and a fairly large amount of paraffin bodies. The specific gravity of coal tar varies approximately between 1·002 and 1·210, or, expressed in another way, 1 gallon of water weighs 10 lbs, and 1 gallon of tar will weigh between 10·02 lbs. and 12·10 lbs.

When tar is submitted to destructive distillation (that is, heated in a closed vessel provided with a small outlet pipe, through a range of high temperatures which brings about a splitting up of many of its ingredients into lighter and more volatile ones), a very large number of chemical compounds are obtained, approximately about two hundred. Among these are benzene, toluene, the xylenes, naphthalene, anthracene, carbolic acid, the cresylic acids and pyridine.

Not so many years ago, tar was employed in almost the same condition as that in which it was received from the gas works (that is to say, it was allowed simply to remain at rest in tanks until the larger portion of the entangled ammonia water had separated) for the purpose of painting iron or steel structural work to protect it from rust, the painting of the sides of houses to render them damp-proof, and on roads to allay dust and to increase their wearing properties. At the present time, however, this is not allowed, as it means wasting the many valuable materials which can be obtained from the tar by submitting it to the process of destructive distillation. The residue left on distillation—pitch—after adding to it while it is hot a certain amount of creosote oil, is sometimes used for the purposes just mentioned. However, the results obtained by the use of this preparation are not always quite satisfactory. At the present time large quantities of the so-called prepared tar are employed for the treatment of roads. To prepare this material coal tar is submitted to a partial distillation, which removes all the ammonia water, naphthas and oils containing carbolic acid. The residue is allowed to cool somewhat and is then pumped into storage tanks, or direct into barrels, and sometimes into the tar-spraying carts which have now become such familiar objects in all our towns and cities. The storage tanks for this kind of prepared tar are often fitted with steam coils so that the tar may be kept hot and thus supplied to the tar-spraying carts at a temperature almost high enough for use. The spraying carts are fitted with steam coils in order further to heat the tar and to keep it at the correct temperature whilst applying to the roads. Much of the prepared tar employed for road treatment is now supplied in the form of an emulsion with water, so that it can be applied to damp road surfaces.

A tar prepared in a somewhat similar manner to that just described is employed in the manufacture of roofing felt. In the preparation of this material a special kind of felt (millboard) is passed through the prepared tar which is placed in a tank heated by means of steam passing through coils. The felt, which must be quite dry, is slowly unwound from a roller fixed at one end of the tank, and after immersion in the hot tar passes between two rollers fitted near the other end of the tank, the function of which is to squeeze the excess of tar out of it. The felt is then sprinkled with fine grit, sand, cork or other suitable material, and after this, wound on another roller. It is removed from this roller from time to time in a condition ready for sale.

From the remarks already made the reader will have probably gathered that the value of coal tar is considerably enhanced by submitting it to the process of destructive distillation. That this is so is made very evident by the fact that some of the materials obtained by this process are used in the explosive, dye, paint and varnish, artificial drug and india-rubber industries. Others of the products are used as fuel and for wood preservation; very large quantities indeed are employed for the latter purpose on railway and telegraph systems.

At the outset the reader must not be misled into thinking that the products (called distillates) obtained by submitting tar to distillation are ready to be used for the manufacture of the materials just mentioned. It is necessary to put the distillates through operations which are many and varied, as will be seen in the chapters which follow.

There are two systems employed for the destructive distillation of tar, the intermittent and the continuous, and at the present moment the former system is the one most used; the latter, however, is growing in favour. The continuous system is used largely for the manufacture of road tars, and is installed in many gas works and tar distilleries.

The yield of distillates from coal tar varies a good deal, but in order to give the reader some idea of the results obtained the following figures are given—

TABLE 1.

Material.	*" High temperature." Gallons per ton tar.*	*" Low temperature." Gallons per ton tar.*
Ammoniacal liquor	4·0	5·0
Crude naphtha	3·8	24·0
Light oil	17·0	48·0
Carbolic oil	10·7	27·0
Creosote oil	26·8	5·0
Anthracene oil	5·2	—
Pitch	13·35 cwt. per ton	10·0 cwt. per ton

From the crude naphtha and light oil are obtained benzol, naphthas and pyridine bases; carbolic and cresylic acids are recovered chiefly from the middle or carbolic oil. The yields of these products obtained from a ton of tar varies, and they average out according to the figures shown in Table 2.

TABLE 2.

Material.	*Gallons per ton tar.*
90^s Benzol	2·00
Naphthas	4·30
Pyridine bases	0·25
Carbolic acid (crude)	3·50
Cresylic acids (crude)	3·80

The amount of coal tar produced in the United Kingdom at the present time is very considerable, being approximately 353,000,000 gallons per annum.

CHAPTER II

In the intermittent process of tar distillation the tar is run by force of gravity or else pumped into a vessel termed a tar still (Fig. 2). The working capacity of tar stills varies between ten and fifty tons, and they are constructed of iron or steel plates very carefully riveted together in order to avoid leakage. The top of a still is made in the form of a low dome, and the bottom is more or less concave if viewed from the outside. On the side at the bottom is fixed a short pipe to which is attached a cast-iron cock or tap. This pipe is for the purpose of running out of the still the residue left after distillation, and is called the "run off" or discharge pipe.

In the middle of the dome is fixed a cast-iron pipe, angular in form, known as the swan-neck. A safety valve, an inlet for a steam pipe and an inlet for a thermometer are also fitted on the dome. To enable workmen to get inside the still for cleaning purposes and to conduct repairs a hole is cut in the dome, called a manhole, and to this a tight lid is fitted. On the side of the still, near the dome, is fixed a short pipe called the tar inlet pipe. Inside the still, at the bottom, a perforated steam coil is arranged, the use of which will be explained later.

The still is placed upon a support of brickwork (the seat), and under the still is built a fire-grate and ash-pit. (*See* Fig. 1 (*Frontispiece*), also Figs. 3 and 4.) The flames and hot gases from the fire are carried round the outside of the still by means of flues, which are built of fire-brick and to a height nearly half-way up the still. The remainder of the outside of the still, and also the dome, are covered with brickwork, the object of this being to prevent loss of heat by radiation. In some works tar stills are heated by means of producer-gas instead of a coal fire. In cases like these a special gas-burner is fitted in such a position that the gas burns over the fire-grate in the space called the combustion chamber. Producer-gas is prepared by passing air and steam at the same time over red-hot coal or coke contained in a specially constructed apparatus, and it is conveyed to the burners at the still furnaces through a large culvert-like construction of fire-brick. The rate of the supply of gas to the orifice of the burners is controlled by means of a valve, and the air which is mixed with the gas in order to secure proper combustion is governed in a similar manner.

For the purpose of distillation a tar still is never completely filled with tar, but only to about three-quarters of its total volume. This is to allow for the expansion of the tar when it is heated and for the easy escape of vapours when high temperatures are reached. When the still is properly charged, the fire is lighted, or the producer-gas ignited, and the tar raised fairly rapidly to a temperature of about 95° Cent. (203° Fah.). At this temperature vapours commence to come away from the tar, and these consist of water, ammonia, benzene, toluene, and some other low-boiling tar oils. When this point is reached, the heating is conducted cautiously in order to prevent the tar from boiling over. The temperature of the tar rises gradually and the vapours as they come off are conducted by the swan neck to a long length of pipe which is arranged in the form of a coil and which is known as the condenser coil. This coil (*see* Fig. 4) is made of wrought iron or cast iron, and it is placed in a tank constructed of wrought iron or mild steel plates so that it can be completely immersed

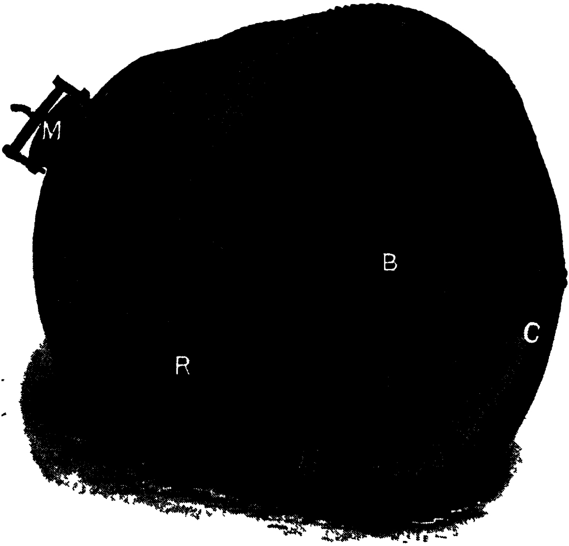

FIG 2

TAR STILL (LYING ON ITS SIDE)

M.—Manhole and lid
B.—Bottom
R.—Run-off pipe
C.—Channel Plate

in water. The object of doing this is to abstract heat from the vapours and so cause them to become liquids again (to bring about condensation).

The water tank, or condenser tank (*see* Figs. 1 and 3) as it is termed, is supplied with a water inlet pipe which goes almost to the bottom, and also with a water outlet. On the inlet pipe is fitted a tap to enable the still-man to cut off the supply of water when required. A perforated steam coil is arranged on the bottom of the tank so that the water can be heated if necessary during one stage in the distilling operation. While the vapours of ammonia and the lighter coal tar oils are coming away from the distilling tar, cold water is allowed to flow through the condenser tank.

The vapours of the substances just mentioned when they become condensed, separate into two liquids, one being watery and yellow in colour and smelling strongly of ammonia, and the other oily and of a specific gravity, a little lighter than pure water. In the technical world the former is called ammoniacal liquor and the latter crude naphtha.

These liquids, on leaving the end of the condenser coil (which projects through the bottom of the condenser tank) run into a small iron receptacle shaped like a rectangular box. This box, which is provided with a sliding lid, is used by the still-man to inspect the liquid (known as distillate) as it leaves the end of the coil, and also to take samples for the purpose of testing. Connected to this observation box (in addition to the condensing coil) are three pipes, one of which is to carry away foul gases. Of the other two, one is used to conduct the ammoniacal liquor and crude naphtha to a separator, and the other (called the common main) is for the purpose of leading the distillates which come from the tar after the crude naphtha has distilled

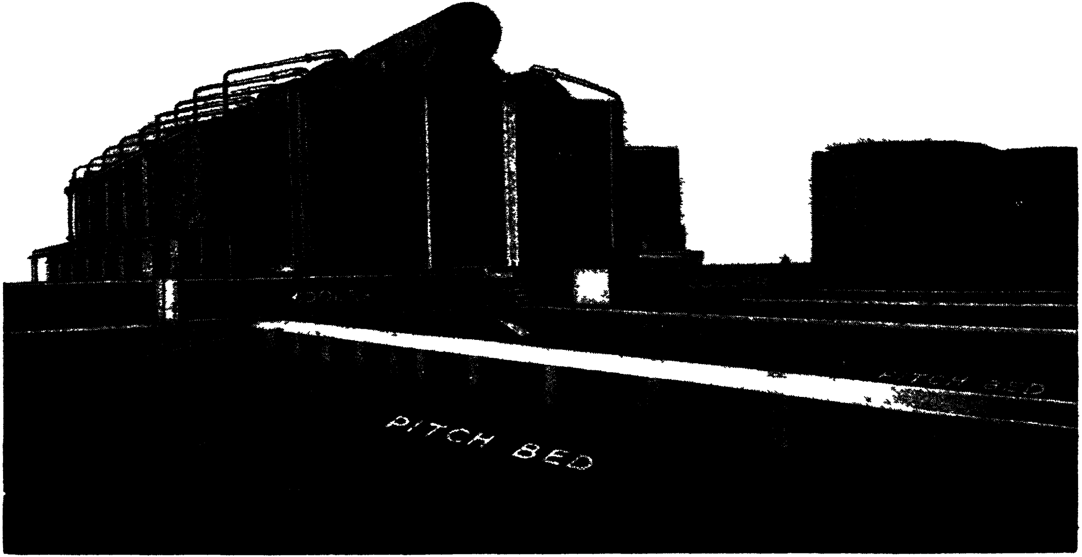

Fig 3

BATTERY OF TAR STILLS (INTERMITTENT SYSTEM) off, into their respective mains, which, in their turn, conduct them to large tanks called receivers.

The crude naphtha and ammoniacal liquor immediately they get into the separator, divide, the latter falling to the bottom and the former rising to the top of the apparatus. This separation is continuous, and each liquid is lead away by a pipe to its respective receiver.

The receivers are constructed of iron or steel plates riveted together, and they vary in size and shape in different works. They are provided with a manhole and lid, a small vent on the top to enable the still-man to measure the contents by means of an iron rod, an outlet pipe which is connected to a pump for the purpose of removing the contents to a storage tank or other receptacle and, with the exception of the ammoniacal liquor and crude naphtha receivers, a closed steam coil. This coil is laid upon the bottom of the receiver, and is used when necessary to warm up the distillates so that those portions which become solid will dissolve, and the whole may be pumped away.

It takes several hours to distil off, or to use the technical term, " work off," the ammoniacal liquor and crude naphtha from the tar. The actual time taken will depend upon the amount of ammoniacal liquor entangled in the tar, and the volume of the charge of tar in the still. The greater the quantity of liquor contained in the tar, the slower the operation of distillation. After a time the amount of ammoniacal liquor coming over with the crude naphtha begins to decrease, and the temperature of the distilling tar in the still rises. When the temperature reaches about 180° Cent. (356° Fah.) the still-man shuts the tap on the pipe which leads to the separator and opens the tap on the common main. This main, as already

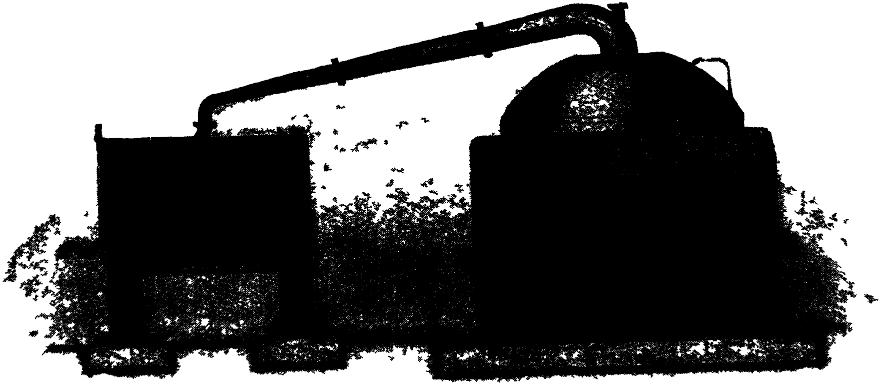

Fig 4

STILL (SURROUNDED BY BRICKWORK), AND CONDENSER AND COIL
(SHOWN IN SECTION)

explained, is connected to several pipes each running into a receiver, and to each of these pipes is fitted a tap so that the still-man can shut off one receiver from another.

The distillate which follows the crude naphtha is called light oil, and this flows through the common main into the pipe which leads to the light oil receiver. Shortly after this fraction has commenced to come off, the still-man makes a larger fire or increases the gas supply. This is done to raise the temperature of the distilling tar and so ensure a continuous stream of distillate. The water supply to the condenser tank is also shut off, and the water in the tank allowed to get hot by absorbing heat from the distillate as it flows through the condensing coil. This is necessary, for, when about half the volume of the light oil has distilled off the tar, that which follows sets to a semi-solid mass when cold and it would choke up the condenser coil, and this would probably cause an explosion due to the pressure which is set up because the vapours leaving the tar cannot escape via the condenser. The solidification is due to the presence of naphthalene and its congeners in the oil.

When the temperature of the tar in the still reaches about 225° Cent. (437° Fah.) the still-man shuts the tap on the light oil receiver main and opens that on the main leading to the carbolic oil receiver. The distillate now coming from the tar is called carbolic oil and, as indicated by its name, it contains carbolic acid or phenol. The cresylic acids are also present in, and are recovered from this oil. Owing to the fact that this distillate very often contains a fairly large quantity of naphthalene, the water in the condenser tank is kept hot, if necessary by passing a little steam into the water through the open steam coil at the bottom of the tank. The fire under the still is increased in intensity as this fraction comes off, and when the temperature of the tar in the still reaches about 255° Cent. (491° Fah.) the still-man diverts the flow of the distillate into the creosote oil receiver by manipulating the taps on the receiver mains. All the time the creosote oil is running through the condenser coil, the water in the tank is kept hot in order to avoid any risk of the coil becoming choked up, due to the solidification of naphthalene which is present in the oil. As a matter of fact, it is the usual practice to keep the water in the condenser tank at almost boiling point while this and the next (the final) fraction, which is called anthracene oil, are coming off.

The change from the creosote to the anthracene oil fraction is made when the tar in the still reaches the temperature of about 275° Cent. (527° Fah.). After the anthracene oil fraction has been flowing for a short time, the fire is allowed to die out and steam is introduced into the tar via the open steam coil, which, as has already been mentioned, is fitted at the bottom of the still. The object of doing this is to reduce the temperature of distillation during the final stages. If this were not done, the wear and tear on the still would be far greater than it is. Steam has the power of reducing the temperature at which many substances distil. The anthracene oil fraction is allowed to flow until the temperature of the contents of the still has reached about 320° Cent. (608° Fah.). The steam is then shut off and any fire which may yet remain in the furnace raked out.

In many tar distilleries a thermometer is not used to determine the finishing point of each fraction, but the still-man is given certain specific gravities to work to. These specific gravities vary somewhat, according to the kind of tar undergoing distillation, and it would not serve a useful purpose to quote any of them in an elementary book of this sort; in fact it would tend to confuse the general reader.

The residue in the still, *i.e.*, pitch, is allowed to remain for some hours before it is removed, or "run off," as it is termed in the tar distillery. This is necessary, for if very hot pitch is run out of the still it is liable to catch fire, and also the iron work and joints of the still would be subjected to the great heat remaining in the brickwork of the flues, which would cause considerable damage.

The outlet through which the pitch is run is at the bottom of the still in the position already referred to. This outlet pipe, or "run off" pipe as it is termed, is connected to a vessel called a pitch cooler (*see* Fig. 3). In most tar distilleries this vessel is made of wrought iron or mild steel plates strongly riveted together and arranged so that it is surrounded entirely by the atmosphere. It is fitted with a foul gas outlet (which is connected to a foul gas main), a manhole and lid, a safety contrivance to relieve any pressure which may be set up, and an outlet valve through which the cooled pitch is run when ready for the pitch bay.

The pitch bay (*see* Fig. 3) is a large shallow excavation lined with hard bricks and constructed so that one edge is under the valve of the pitch cooler. In some tar distilleries a gutter is built under the valves of the pitch coolers, and this gutter has outlets which communicate with the pitch bay. The pitch is kept in the cooler for a number of hours, and the object of doing this is to allow its temperature to fall to that at which a minimum of irritating vapours are given off and to do away with the risk of these vapours catching fire spontaneously. When the pitch is ready, it is run on to the

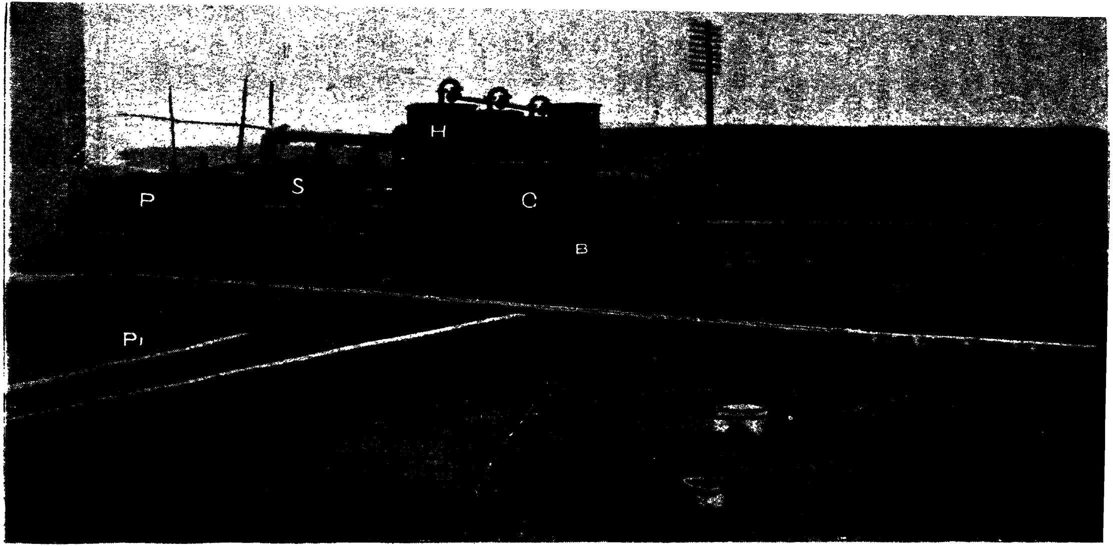

FIG. 5

HIRD'S CONTINUOUS TAR DISTILLATION PLANT

S.–Still. H.–Combined heater-cooler. C.–Coil condenser. B.–Sight-box. P.–Pitch cooler. P1.–Pitch bay.

floor of the bay and is allowed to form a layer of about 6 in. thick. In order to facilitate the removal of the pitch, the floor of the pitch bay is whitewashed. When the pitch is cold it is broken up by means of steel wedges and heavy hammers, the large pieces being reduced in size with picks. The broken pitch is then removed from the bay in wheelbarrows or in crane skips and loaded into railway wagons, carts or lighters.

The plant required for the continuous distillation of tar (*see* Fig. 5) is more compact than that used in the intermittent process, and for a given output, very much smaller. The wear and tear on a continuous plant is not so great as that experienced on an intermittent plant, and the results of practical work indicate that the continuous system is the most economical. At the present moment there are on the market several patent plants suitable for the continuous distillation of tar, and in order to give the reader a general idea of this system a short description of the Hird process follows.

Tar, that which has been allowed to settle for some time for preference, is run into a charge tank, which is fitted with a regulating arrangement so that it can supply automatically a pre-determined volume per unit of time to the first of a series of three or four stills. On its way to the still, the tar passes first through tanks which contain condensing coils, and then through a pipe arranged in a pitch cooler (*see* Fig. 5). During its passage through these pieces of plant it becomes heated by absorbing heat from the distillates flowing through the coils and also from the hot pitch as it runs through the cooler. It should be noted that tar is used instead of water, as in the intermittent system, to cool the distillates, and this means economy in the way of fuel as the tar reaches the still at an elevated temperature. While the tar is passing through the condenser tanks, or heater-condensers as they are called, the ammoniacal water and crude naphtha are driven off in the form of vapours, and these are conducted by means of a pipe to a common main and along this to the coil of a water condenser. Leaving the coil in the liquid state they pass through a separating apparatus and from this into their respective receivers.

The hot tar, on passing through the first still, meets several baffles which cause it to take a circuitous route before coming to the outlet which leads to the inlet of the second still. During the passage of the tar through the still, the temperature is raised by means of flames and hot gases from large gas-burners which pass through tubes fitted along the bottom of the still, which is cuboid in shape. The vapours which are given off are those of the light oils, and they are conducted by means of a swan-neck outlet to the coil of the heater condenser, and on leaving this piece of apparatus, through a water-cooled coil. The condensed vapours, as they leave this coil, pass into an inspection box and then to a receiver or storage tank.

The hot tar leaves No. 1 still and enters No. 2 still by means of a short pipe which is covered with a non-conducting material. The object of this is to reduce the loss of heat by the tar to a minimum. In its passage through No. 2 still, the tar is baffled in the same way as it was in the first still and additional heat is supplied to it by means of gas-burners. In No. 2 still, creosote oil is driven off, and its vapours are condensed in coils of similar construction to those attached to No. 1 still. The creosote oil, on leaving the condenser coil, passes through the inspection box and then to its receiver. From No. 2 still the tar flows through a short pipe into No. 3 still, and here the anthracene oil is driven off.

No. 3 still is not heated by gas, but has perforated steam pipes fitted inside, and the steam which passes through these pipes, assisted by the heat contained in the tar, is sufficient to distil off the anthracene oil. The vapours of this oil pass through condenser coils similar to those already described and then to a receiver.

The hot residue in No. 3 still, liquid pitch, runs through the outlet into a piece of apparatus called a pitch cooler (*see* Fig. 5). During its travel through the cooler the pitch is reduced in temperature, and on its discharge into the pitch bay hardly any disagreeable fumes are given off. The cooling of the pitch is effected by the passage of tar at a lower temperature through an arrangement of pipes in the cooler. The tar enters immediately after it leaves the heater condensers, and on leaving the cooler runs into No. 1 still as previously described.

Either coal gas or producer gas can be used for heating No. 1 and No. 2 stills, but on most plants of the type just described the latter kind of gas is employed. In the case of some of the larger plants, a coke breeze furnace is the source of heat supply, the hot gases from the furnace passing through tubes fitted in the stills in a similar way to those which are used for the purpose of gas firing.

On reviewing the processes just described it will be seen that a residue of pitch and the following distillates are obtained from coal tar: ammoniacal liquor, crude naphtha, light oil, carbolic or middle oil, creosote oil and anthracene oil. In the chapters to follow many of the products prepared from them are dealt with.

CHAPTER III

PITCH, the residue left in the still when coal tar is distilled, is a black material which consists of a mixture of several high boiling substances chiefly of the aromatic series of organic compounds, and finely divided "carbon."

The hardness of pitch will vary according to the total amount of distillates worked off the tar and the greater this amount the harder the pitch. There are several grades of pitch manufactured of which the chief are soft, medium and hard, and of these three the medium grade is made in the largest quantity. Soft pitch will flow slowly during the summer months, and for this reason it is packed in casks or barrels. The medium and hard grades are sold loose in lumps, and are in this form loaded into the holds of ships or lighters and into railway trucks. Shipments of medium pitch are not often made during the summer months, as there is a tendency for the lumps of this grade to stick together during the warm weather. All the grades of pitch are glossy on a freshly-melted surface, but the medium and hard qualities, when broken, are dull on the faces of the fracture, the latter grade showing the duller surface. The specific gravity of pitch varies between 1·190 and 1·340, and its melting point between 36° Cent. (96·8° Fahr.) and 120° Cent. (248° Fahr.).

Pitch is employed in several industries, and at present new outlets are being looked for in order to cope with the increasing make. Large quantities of pitch are used in the manufacture of patent fuel or briquettes. A medium pitch is required for this purpose, and it is mixed with coal dust or coke breeze and the mixture then heated by means of superheated steam. The well mixed and heated mass is allowed to fall into specially designed moulds, and these when full come into position under a hydraulic ram which compresses the contents into a hard block. The blocks, or briquettes, are forced out of the moulds and are carried by mechanical conveyors to storage or to the loading quay. The briquette industry is one of importance, and the chief works in Great Britain are situated in South Wales. Briquettes are used for firing boiler furnaces of steamships and locomotives, and on a smaller scale for domestic fires. The larger quantity of those made in Britain are exported to the Continent, chiefly to France, Belgium and Spain.

For the manufacture of pitch-grouted macadam, which is used for road-making and also for running in between the stone and wooden sets of roads, a rather soft pitch is employed, which, owing to its ability to bind and also to give under pressure, proves an excellent material for this purpose. A moderately hard pitch finds extensive use in the manufacture of tar or black varnishes. These preparations consist of solutions of pitch in coal tar distillates, the chief distillates being creosote oil and heavy naphtha. They are prepared for the protection of iron and steel work from rust, the painting of ships' topsides and bunkers, for waterproofing exposed walls of houses, and numerous other purposes.

Other uses for coal tar pitch are its employment in the manufacture of basic (magnesian limestone) linings of furnaces of steel works, in the making of special roofing materials, for preparing sand cores which are used in the making of iron castings, and as a fuel.

The amount of coal tar pitch produced annually is large, being 369,104 tons in 1928 and 391,861 tons in 1929.

From the figures on page 7, the creosote oil fraction is obviously the largest of all the fractions obtained when coal tar is subjected to high-temperature distillation. The volume of this fraction will vary according to the kind of tar distilled, the points at which the fraction is commenced and finished, or whether the anthracene oil fraction is mixed with the creosote fraction or not. As a rule it varies between 9 and 25 per cent. of the tar. Some types of creosote oil are liquid at ordinary temperatures, and there are grades which will remain liquid at the temperatures at which water freezes. Other kinds of creosote oil contain naphthalene " salts " in varying quantities, and some creosotes of this type are quite solid at a temperature of 60° Fahr. The amount of phenols, or in technical language, " tar acids," in creosote oils varies from a few per cent. up to about 25 per cent. Practically all qualities of creosote oil are heavier than water, the specific gravity varying approximately between 1·01 and 1·065, and the colour is usually a dark reddish-brown. A good marketable quality of creosote should not contain more than 3 per cent. of water, and it must be free from dirt, partly dissolved tar or other foreign materials.

Great Britain produced 58,586,546 gallons of creosote in 1928, and 58,796,131 gallons in 1929.

The world's consumption of creosote oil is very considerable, and there is every indication of its increasing. Large quantities are used for the manufacture of sheep dips and disinfectants, for fuel, and in the recovery of benzol and toluol from coal gas, but by far the largest quantity is used for the preservation of timber. The total amount of creosote imported into the U.S.A. during 1928 was 88,385,074 gallons from the following sources: Great Britain, 44,009,816 gallons; Belgium, 21,977,802 gallons; Netherlands, 18,312,329 gallons; Canada, 1,475,919 gallons; Japan, 1,450,574 gallons; Germany, 1,158,661 gallons. During the year 1926, 185,733,180 gallons of creosote were consumed in the United States of America for this purpose. The greater part of this enormous quantity was used to preserve railway sleepers and the balance for the preservation of piles, telegraph poles, pavement blocks, and constructional timber. There are several processes employed for treating wood with creosote oil, and of these, the chief are the Bethell process, the Boulton process, the Lowry process, the Rueping process and the Colman process. A short description of the Boulton process will no doubt be of interest to the reader. The timber to be treated is placed upon a special truck which runs on rails and which can be pushed into a large cylinder. This cylinder is made air-tight by means of a specially fitted door, and is connected to a vacuum pump and also a pump for pumping creosote oil into the cylinder under pressure. A truck load of timber having been run into the cylinder and the door tightly closed, a vacuum is produced by the vacuum pump and is maintained for about an hour. This removes a considerable amount of water from the timber. The vacuum is now destroyed and creosote oil pumped into the cylinder until a pressure of between 110 and 170 lb. per square inch is reached. This pressure is maintained until the timber has absorbed the required amount of creosote oil; this varies between 6 and 24 lb. per cubic foot. The pressure is then reduced, the cylinder drained and the truck carrying the timber removed. Sometimes the creosoted timber is put under a vacuum for a short time before removing it from the cylinder.

The quality of the creosote oil used for the preservation of timber varies a good deal, each user having his own specification. Some prefer a large quantity of naphthalene in the oil and others require an oil almost, if not quite, free from this material. The percentage of tar acids allowed to be present will vary also according to individual ideas.

Creosote which is intended for use as a fuel oil must be quite free from dirt and naphthalene and not contain much more than a trace of water. Special burners are employed for burning this oil, and the orifice of the jet being small it is easily choked by particles of dirt or naphthalene. An excess of water is liable to put the flame out, and if this occurs and is not noticed immediately considerable trouble will result. The calorific value of creosote oil varies little, an average figure being 16,630 B.Th.U. Comparative values for petroleum fuel oil and coal are 18,250 B.Th.U. for the former and 14,500 B.Th.U. for the latter. From these figures it will be seen that creosote oil comes between petroleum and coal as a fuel. For the reader's guidance, it should be explained that a B.Th.U. (British Thermal Unit) is the amount of heat required to raise 1 lb. of water through 1° Fahr., and therefore 1 lb. of creosote fuel oil will raise 1 lb. of water 16,630° Fahr. or 16,630 lb. of water 1° Fahr.

For the manufacture of sheep dips and disinfectants, a creosote oil is required which contains a fair amount of tar acids, only a little water, and not any naphthalene.

It is from creosote oil that large quantities of naphthalene are recovered. Much larger quantities are obtained from carbolic oil after it has been treated for the removal of the phenols. The oil is run into large shallow tanks which are artificially cooled, and its temperature reduced to somewhere about the freezing point of water. This causes the naphthalene to separate out in the form of crystals. After a period of rest at this low temperature, the portion of the oil which still remains liquid is drained off and the crystals of naphthalene taken out of the tank and placed into centrifugal machines.

A centrifugal machine (*see* Figs. 6, 7 and 8) consists of a short cast-iron cylinder, open at the top and closed at the bottom with the exception of an outlet hole. Inside this cylinder is another, the curved surface of which is made of perforated plates, and which is called the basket. The basket is attached to a shaft which is suspended from a large cast-iron bracket. To the shafting is fitted a pulley wheel, and it is driven at a high speed by means of a belt which is attached to the pulley wheel of the shaft and to an electric-motor or steam-engine. The motion of the shaft causes the basket to revolve very rapidly (speeds up to 1,500 revolutions per minute are used), and by the action of centrifugal force the material in the basket (a mixture of solid and liquid) is thrown against the inside curved surface of the basket which is covered with a special lining full of fine perforations, the solid being retained while the liquid is forced through the fine perforations of the lining. As the liquid comes from the basket it drops into the space between the basket and the case or outside cylinder, falls to the bottom, and runs through the outlet just mentioned and away to a storage tank.

The centrifugalized crystals of naphthalene are now placed in special bags and submitted to great pressure in hydraulic presses, which are sometimes heated, and this gets rid of the remaining traces of oil and some of the entangled impurities. After the pressing, the naphthalene is put into a cast-iron jacketed vessel fitted with an agitator, melted by means of steam, which is introduced into the jacket, and treated with a small quantity of strong sulphuric acid. Following the acid

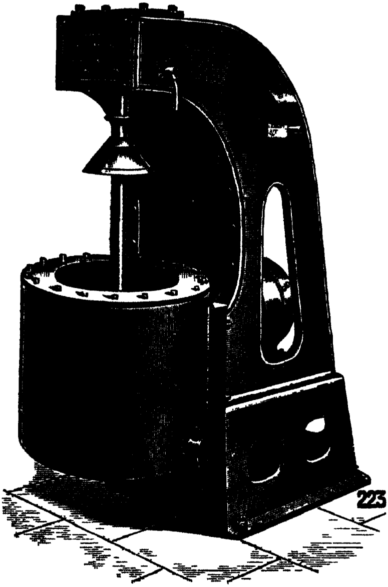

FIG. 6

CENTRIFUGAL MACHINE

treatment there is one with water, and then one with alkali. The object of submitting the naphthalene to the action of these chemicals is to remove impurities which will not come away during the pressing operation.

The next part of the process is to submit the chemically treated naphthalene to distillation or sublimation. If the naphthalene is to be distilled it is put into a still something like a tar still, and the pure substance which distils off is passed through a heated condenser coil into a receiver where it crystallizes out. The process of sublimation is rather different, the naphthalene being placed in a shallow pan over which is fitted a dome-like cover. The naphthalene is carefully heated by means of steam passing through the coils placed on the bottom of the pan, and this converts it into a vapour which rises and is condensed on the top and sides of the cover in the form of crystals. At intervals the steam is shut off, the cover lifted and the crystals of naphthalene removed. There are other types of sublimation apparatus in use, but it is not necessary to describe them in this small volume.

Pure naphthalene is used very largely in the manufacture of coal tar dyes. It is a white substance which crystallizes in the form of large plates; it is marketed to the general public in the form of balls or short sticks, and it is often sold under the name of "albo carbon."

Among the many coal tar dyes prepared from naphthalene are naphthalene black, naphthol black, jet black, naphthalene acid black, cloth scarlet, cloth red, the naphthalene greens, Manchester or naphthalene yellow, diamine brown, diamine violet and diamine sky blue.

The fact that naphthalene is one of the raw materials required for the manufacture of artificial indigo must not be overlooked. It is interesting to note that the

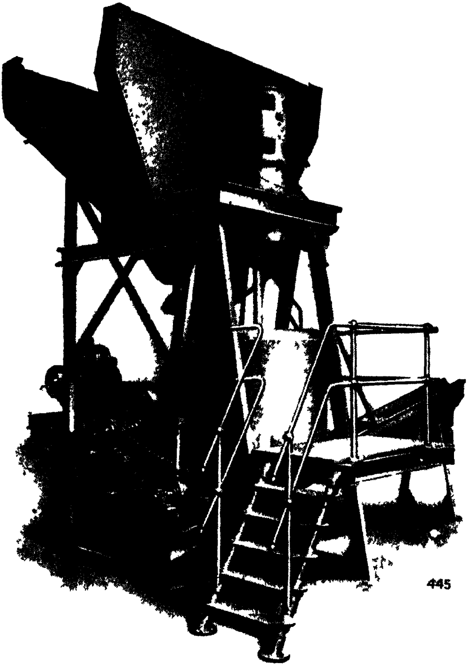

FIG. 7

CENTRIFUGAL MACHINE

Showing feed hopper, screw conveyor to remove the centrifugalized material, driving motor and gear.

large German coal tar dye manufacturers considered the production of artificial indigo of such importance that they spent upwards of £1,000,000, and their chemists devoted nearly twenty years in research before a process was discovered which made it possible to manufacture in an economical way.

Naphthalene finds application in the manufacture of a very fine soot (carbon black) which is sometimes called vegetable black. This material is largely employed in the paint and varnish industry, and it is prepared by burning naphthalene in air insufficient in amount to result in complete combustion and condensing in large chambers the black smoke which is given off.

In the manufacture of celluloid, naphthalene is sometimes used in the place of camphor. Celluloid consists of a mixture of nitro-cotton (a very highly inflammable substance) and camphor, naphthalene or other suitable material. The proportion of the nitro-cotton is approximately 40 per cent., and that of the camphor or other material 60 per cent. If the celluloid is prepared from nitro-cotton and artificial camphor the addition of naphthalene renders it uninflammable and unexplosive. In the practice of medicine naphthalene is employed as an antiseptic, as an intestinal disinfectant, and as an ingredient of parasiticide ointments.

As the amount of tar distilled gets larger, so will the production of naphthalene increase; hence chemists are searching for new uses for this material. One of the latest is an attempt to employ naphthalene as a motor fuel, and the results of experiments have so far been very encouraging; a motor boat engine has been driven satisfactorily on this fuel.

The quantity of crude naphthalene produced in 1928 amounted to 14,141 tons, and in 1929 34,970 tons, whilst the amount of refined naphthalene manufactured

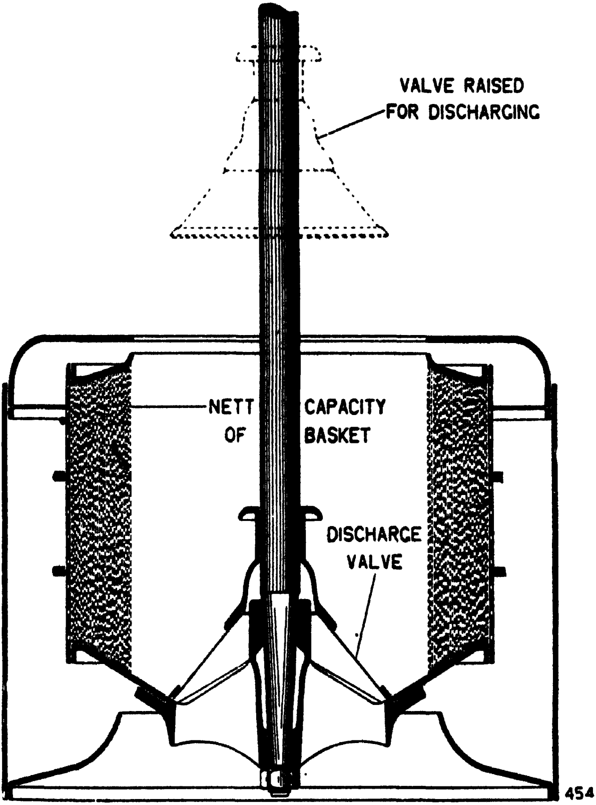

FIG. 8

CENTRIFUGAL MACHINE (SECTION)

in the United Kingdom is somewhere about 300,000 cwt. per annum, absolute figures are not available.

Anthracene oil is yellowish-green in colour, somewhat viscid, more or less greasy to the feel and pasty on account of the presence of crystals of crude anthracene. Owing to its colour anthracene oil is sometimes called green oil. Its specific gravity varies as a rule between 1·065 and 1 110, a gallon weighing between 10·65 lbs. and 11·10 lbs.

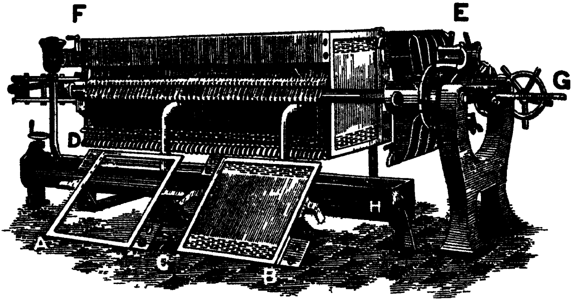

FIG 9

IRON FILTER PRESS

A—Frame B—Plate C and D—Outlets E—End Plate (movable) F—Inlet G—Closing device H—Trough to catch filtrate.

As will be seen later, anthracene is a useful material to the manufacturer of coal tar colours, and in order to place it on the market in a suitable form it must be separated from the liquid in which it occurs and then purified. There are one or two processes by which this is done. In some works the anthracene oil is allowed simply to remain in storage tanks for some time at as low a temperature as can be secured without employing artificial means of cooling. As much as possible of the

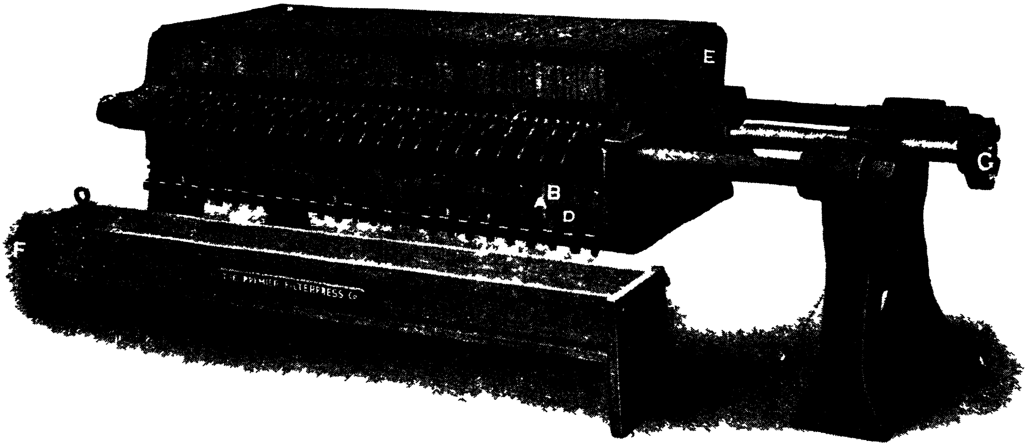

FIG 10

FILTER PRESS WITH WOODEN PLATES AND FRAMES

A —Wooden frame B —Wooden plate C and D —Outlets E —Movable end plate. F —Trough to catch filtrate. G —Closing device.

clear oil is then run off by decantation to a special storage tank, and the thick sludgy mass remaining at the bottom of the settling tank pumped into pipes which have many outlets on the under side to which are tied long linen bags. The bags are filled up and the remaining liquid entangled in the impure anthracene gradually percolates through the interstices of the linen and drops into a tank underneath. In some cases the anthracene sludge is pumped into an elevated tank so that the pipes upon which the bags are suspended are filled by gravitation and a pressure supplied by means of the " head " of sludge. This process is a very slow one, and where large quantities of anthracene have to be dealt with its use is out of the question. A much more rapid process is employed which is briefly as follows: The anthracene oil is run into large shallow tanks which are situated in an artificially cooled room or else the tanks are fitted with cooling coils. It is allowed to remain in these tanks until the whole of the anthracene has precipitated out and then pumped through a filter press (*see* Figs. 9 and 10).

Briefly, a filter press consists of a number of recessed iron plates upon the sides of which, near the top, brackets are cast. In the centre of each plate is a hole, and near one of the bottom corners of each is fitted a small tap. The plates are hung by means of their brackets on two horizontal iron runners which are supported by iron legs. A blank plate is arranged at each end of the series of recessed plates, and to one of these blank plates is fitted a screw appliance to enable the workman to bring all the plates up together tightly. When in this position, a chamber is formed between each two plates. Before screwing up, special cloths with a hole in the centre are placed between the plates, and it is these cloths which retain the crude anthracene and allow any liquid to pass through them. The liquid, called filtrate, runs out of the taps into a trough and away to a storage tank. Some filter presses are fitted with wooden frames and plates, and many types of both iron and wooden presses have the inlet at one corner instead of the centre.

The anthracene sludge is pumped into the filter press through a hole in the centre of the blank plate which is not fitted with the screwing arrangement, and it runs through the holes in the chamber plates and spreads over the filter cloths on its way. When the press chambers are full the pumping operation is stopped, the press allowed to drain, and then opened and the partly dried anthracene on the cloths, called press cake, removed. The press cakes are broken up, placed in the basket of a centrifugal machine and submitted to centrifugalization which drives off some more oil. After this it is filled into bags, placed in a hydraulic press, and put under high pressure for some time.

The crude anthracene cake from the hydraulic press has to be further purified and the next operation is to grind it up and then wash it in a washing apparatus. This piece of plant is cylindrical in shape, and is made of wrought iron or cast iron. It is fitted with a steam coil, or a jacket, in order that it may be heated by means of steam. For the purpose of stirring the crude anthracene and washing liquid a mechanically-driven agitator is provided. The washer is erected horizontally or vertically, and the charge hole and outlet are arranged according to the position.

The crude anthracene is placed in the washer and on to it is run the requisite quantity of a specially prepared naphtha (or in some cases acetone or pyridine). The mixture is warmed by means of steam supplied to the jacket, or steam coil, and at the same time well stirred by the agitator. When the washing is completed the mixture is pumped into a filter press to remove the washed anthracene from the washing liquid. The anthracene press cakes are broken up and submitted to the process of centrifugalization and are then finally dried on trays in a drying-room. The product is now ready for the aniline colour maker.

To the manufacturer of certain classes of aniline colours, viz., the alizarin reds, oranges and blues, anthracene is a very important material and the purer the crude article the more readily it will find a market; in fact, there are many qualities of crude anthracene which are quite unsuitable for dye manufacture owing to the presence of impurities which are difficult to remove. It should be noted that at present there is more anthracene distilled off coal tar than is required in the coal tar dye and other industries.

In addition to the alizarine colours, anthracene is a source of other coal tar dyes such as anthracene brown, anthracene blue, anthraquinone violet, inanthrene blue, inanthrene grey, inanthrene pink, algol olive, algol brilliant violet, etc.

Anthracene is also the source of the drug anthrarobin which is employed in medicine for the treatment of skin diseases.

The oil remaining after the removal of the anthracene is called strained oil. It is often mixed with creosote oil, and the mixture employed as a timber preservative, and it is sometimes used in the manufacture of blue bricks. Strained oil is very useful as a fuel oil, and as an ingredient of certain classes of sheep dips and disinfectants. This oil, when mixed with a special creosote, is employed in the process of removing benzol and toluol from gas (gas stripping).

CHAPTER IV

THE amount of ammoniacal liquor obtained from coal tar on settling and also on distillation is very small compared with that recovered at a gas works, and many tar distillers dispose of the amount they produce to an ammonia distiller. In some tar distilleries, however, the volume recovered is sufficient to make it worth while to work it up, and on this account, and owing to the industrial importance of this material, a brief description of the process employed to work it up and of the products obtained from it are given in this chapter.

Ammoniacal liquor, or ammonia water, is a yellowish liquid possessing an unpleasant smell something like the odour of bad eggs mixed with ammonia. Its specific gravity is about 1·045, one gallon weighing 10·45 lbs. Ammoniacal liquor consists of a solution in water of several chemical compounds (salts of ammonia), the chief of which are: ammonium chloride (sal ammoniac), ammonium sulphate, ammonium sulphite, ammonium sulphocyanide, ammonium carbonate, ammonium cyanide, ammonium sulphide and ammonium hydrosulphide.

In practice it is not possible to recover these salts direct from ammoniacal liquor, it being necessary to submit the liquor to a process of distillation in which is included a chemical treatment with lime. The use of lime is necessary to decompose and cause ammonia to be given off from those ammonium salts in the liquor which are not decomposed when boiled with water (treated with steam). In the trade all the ammonium salts which are decomposed when boiled with water are classed under the heading of "free" or volatile ammonia, and those whose solutions do not decompose unless they are boiled with lime or other alkali come under the heading of "fixed" ammonia. Some of the former salts are the ammonium carbonates; ammonium sulphide and ammonium cyanide, and a few of the latter are ammonium sulphate, ammonium chloride, ammonium thiosulphate and ammonium ferrocyanide.

Before ammoniacal liquor can be run to the still it must be allowed to remain in a storage tank for some time in order to allow any entangled tar to separate out. This is absolutely necessary, as the presence of tar interferes with the success of the distilling operation. The tar settles to the bottom of the tank, so that the clarified liquor can be run off by a tap placed at a suitable height from the tank bottom.

An ammonia still is not anything like a tar still in construction, in fact it is really a column built up of specially designed plates. There are several types of ammonia stills, but they vary in certain constructional details only, the principle being the same in all cases. The still and its accessories make a more or less complicated plant, and one rather difficult to describe to the non-technical reader (*see* Figs. 11, 12 and 13).

The plates just mentioned are cast on the inside curved surface of short cylinders called sections or segments, and the number of these segments, and, therefore, plates, superimposed in a column averages at about twelve. The design of the plant is such that it allows a certain depth of liquor (a seal) to remain on it while it is working. There is an inlet for steam in the centre of the plate, and over this is a hood which has serrated edges. This arrangement causes the steam to divide into jets and to pass through the layer of ammoniacal liquor on the plate. Each plate has an

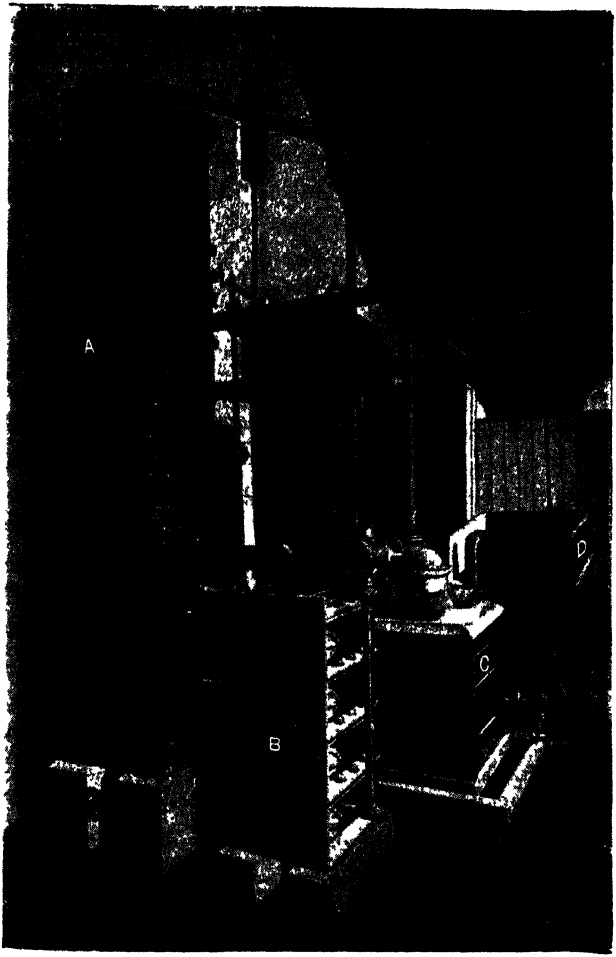

FIG. 11

SULPHATE OF AMMONIA PLANT

A.—Free Ammonia Still. B.—Fixed Ammonia Still.
C.—Saturator. D.—Draining board.

overflow pipe, and these are arranged on opposite sides so that the liquor flows down the column in a zigzag manner. The clarified ammoniacal liquor is run out of an elevated storage tank into a pre-heater (super-heater), entering at the bottom and leaving at the top. A pre-heater consists of a number of tubes enclosed in a cylindrical tank and the liquor runs through these tubes, being heated during its passage by hot gases passing through the cylinder. On leaving the pre-heater the hot liquor enters the first steam section of the still, which is at the top, and flows down as already described. The steam which passes through it on its downward flow, drives off the "free" or volatile ammonia (that is, it decomposes such ammonium salts as the carbonate setting free ammonia), and this is carried out of the still with the steam.

About half-way down the still, and sometimes quite separate from the still, is a chamber into which milk of lime (slaked lime mixed with water to the consistency of a thin cream) is pumped, and this mixes with the liquor which now contains mostly fixed ammonia. The limed liquor now flows over plates similar in construction to those above the liming chamber and meeting with steam, which enters through the distributing hoods, the fixed salts of ammonia are decomposed and the ammonia set free is carried upwards and out of the still by the steam. Decomposition of the fixed salts of ammonia is brought about by the combined action of the lime and steam. The treated liquor, now called "spent liquor," leaves the still at the bottom and after passing through a seal pipe, runs into cooling and settling tanks and then to the sewer.

On leaving the still the ammonia vapours, together with steam and certain foul or waste gases, pass along a pipe to a saturator. This piece of apparatus varies

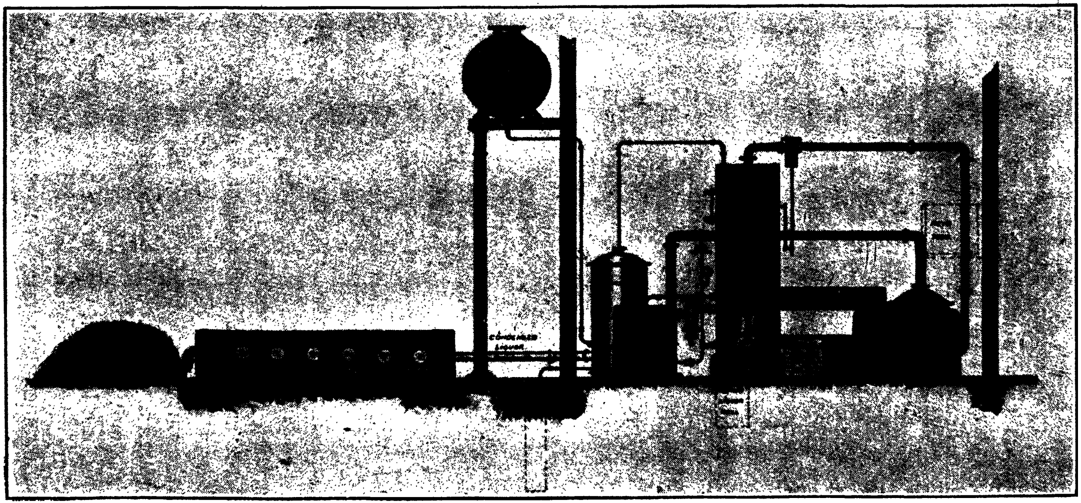

FIG. 12

SULPHATE OF AMMONIA PLANT (ELEVATION)

somewhat in shape according to the ideas of the maker, and it is constructed either of wrought or cast iron lined with thick lead plate. The lead lining is necessary as uncovered wood or cast iron would not withstand the action of the sulphuric acid which is used to absorb or combine with the ammonia, to form ammonium sulphate.

There are three chief types of saturator, viz., the open, semi-closed and closed. If the first type is used, the sulphate of ammonia is removed from it by means of a hand scoop. In the case of the second or semi-closed type, removal of the ammonium sulphate can be carried out by a hand scoop, by a steam ejector, or through a specially constructed valve at the bottom of the saturator. The sulphate is removed from the third or enclosed type either by a steam ejector, or a valve similar in construction to that fitted to the semi-closed type.

The ammonia vapours, steam and waste gases enter the sulphuric acid in the saturator through a perforated lead pipe, and combination between the acid and the ammonia takes place immediately, with the generation of heat. This heat, called the heat of chemical combination, prevents the condensation of the steam which comes along with the ammonia, therefore it leaves the saturator with the waste gases, and they all pass through the pre-heater, giving up much of their heat to the ammonical liquor which is passing through the tubes of this piece of apparatus. From the pre-heater the uncondensed steam and all the waste gases pass through a water-cooled condenser which condenses the steam only, and the waste gases, on leaving this condenser, are led to a purifier; a necessary procedure, as they are very poisonous.

The ammonium sulphate, as it is removed from the

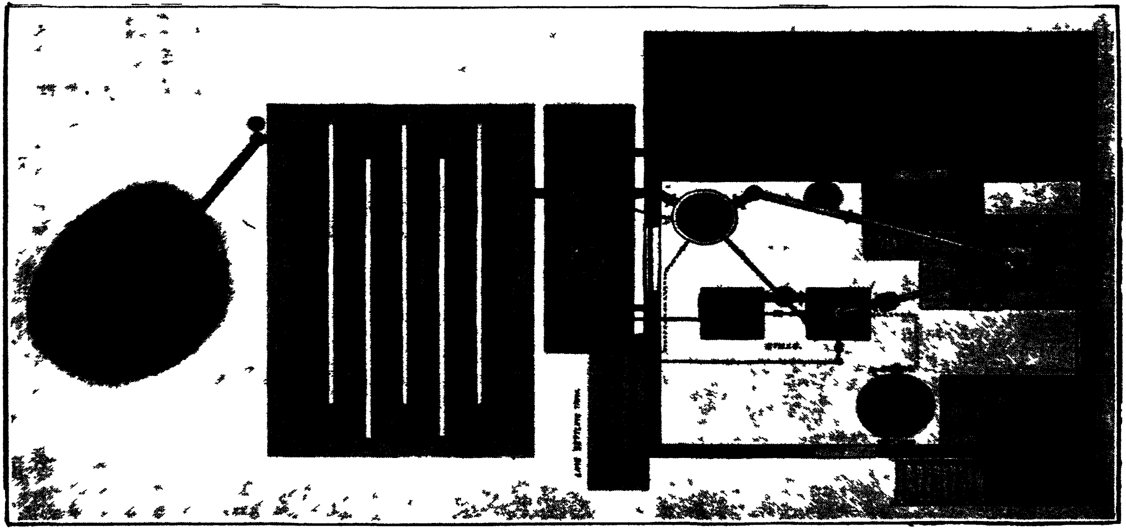

FIG 13

SULPHATE OF AMMONIA PLANT (PLAN)

saturator (it is in the form of crystals), is dropped upon a draining-board or table in order that the entangled acid liquor (called " mother " liquor) may separate and the crystals be left in a more or less dry state.

A draining-board, or table, is a timber structure lined with thick sheet lead, and it is erected in a sloping position. At the bottom of the slope is a trough into which the mother liquor collects, and from this trough it finally runs back into the saturator. The drained ammonium sulphate is transferred to a store shed, or else further dried, before storing, by using a centrifugal machine. The dried salt is generally placed on the market in sacks.

Ammonium sulphate is a very valuable chemical compound to the agriculturist, as on account of the percentage of nitrogen it contains, viz., between 24·25 per cent. and 25 per cent., it can be employed as an artificial manure. It is also an important salt to the manufacturer of ammonium compounds such as ammonium carbonate, ammonium chloride, and ammonium hydrate. Commercial ammonium sulphate is usually of a light grey colour, and it contains a very small amount of free acid and also a little water. The quantity of the latter averages about 1·5 per cent. The production of ammonium sulphate is on the increase, and at present amounts to upwards of 426,000 tons per annum.

Ammonium hydrate, or liquid ammonia as it is called by the general public, is manufactured by several processes at the present time. In one of these it is prepared direct from ammoniacal liquor, and the technical details of this process are carefully guarded by the manufacturers. In some works ammonium sulphate is the raw material, its solution being decomposed by milk of lime, and the ammonia gas which is driven off passed into and dissolved by cold water. Ammonium hydrate is extensively employed both in the chemical industry and in the arts. By far the largest quantity is used in the manufacture of sodium carbonate (washing soda), smaller amounts being consumed in calico-printing, bleaching, in the manufacture of artificial pearls and of some dye-stuffs. It is also used in medicine.

Ammonium chloride, or sal ammoniac, is manufactured in large quantities by decomposing ammonium sulphate dissolved in water with sodium chloride (common salt) or potassium chloride. The ammonium chloride obtained by this process is purified by recrystalization, or by sublimation in cast-iron vessels. This ammonium compound is employed in the electrical industry for charging electric batteries, in the manufacture of some dyes, in the printing of cloth, in soldering and in medicine.

Ammonium carbonate, or lump ammonia, is prepared by mixing ammonium sulphate and chalk with a little charcoal and submitting the mixture to heat when decomposition takes place, and ammonium carbonate is sublimed off. This compound is used in the manufacture of smelling salts and some toilet articles, in the preparation of certain aniline dyes, in the cleaning of cloth and in medicine.

Other important salts of ammonia are ammonium bromide, which is used in photography and in medicine; ammonium fluoride, which finds application in the glass industry for etching glass; ammonium nitrate, which is employed in the preparation of laughing gas and in the manufacture of blasting powder; ammonium phosphate, which finds employment as an artificial manure, and ammonium vanadate, which is used in cloth-printing and dyeing and in the manufacture of black ink.

CHAPTER V

WHEN crude naphtha and light oil are worked up, the following valuable materials are obtained from them: benzol, toluol, xylol, several grades of solvent naphtha, carbolic acid, the cresylic acids, naphthalene, pyridine bases, and a very light creosote; in fact this latter material is more akin to a very heavy naphtha.

Commercially pure benzene, toluene and xylenes, which are important raw materials finding application in the manufacture of aniline dyes, explosives and artificial drugs, are prepared from benzol, toluol and xylol. Chemically pure benzene, toluene and xylenes are obtained from the commercially pure products, and commencing from crude naphtha and light oil many processes of washing, distillation and fractionation have to be carried out before these substances are obtained.

Dealing first with crude naphtha, a measured quantity is pumped from its receiver or storage tank into a piece of apparatus called a washer. A washer is a cylindrical or boat-shaped vessel, constructed of wrought iron or mild steel plates, and provided with inlet pipes at the top for the admission of the oil and the washing material respectively, an outlet valve at the bottom, a manhole and cover, and an agitator which consists of a shaft upon which are fitted blades. The agitator is driven by steam or electric power, and its function is to mix the crude naphtha with the material with which it is to be washed. If the washer is used for washing other oils than crude naphtha a closed steam coil is necessary, and this is fitted on the bottom, its function being to keep the temperature of the oil in the washer above that at which naphthalene salts will deposit. Washers are erected in a horizontal or vertical position according to the ideas of the management, but in all cases above the ground level.

After a full charge of crude naphtha has been pumped into the washer it is allowed to remain at rest for an hour or so in order that any suspended ammoniacal liquor may separate out. The liquor which separates settles to the bottom of the washer and is removed through the outlet valve or cock, and is allowed to flow into a small vessel called a divider. This piece of apparatus is similar in construction to the one used on the coal tar distillation plant, and its object is to retain any crude naphtha which may come along with the ammoniacal liquor. Having separated all the liquor, the crude naphtha is ready to be washed with caustic soda lye (a solution of sodium hydrate or caustic soda in water) in order to remove any carbolic acid (phenol) and its homologues. Sodium hydrate has the power of combining with phenols to form chemical compounds called phenates, and these are soluble in water. The reaction which takes place is expressed by the following chemical equation—

$$\begin{array}{ccccccc} C_6H_5OH & + & NaOH & = & C_6H_5ONa & + & H_2O \\ \text{Carbolic Acid.} & + & \text{Caustic Soda.} & = & \text{Sodium Phenate.} & + & \text{Water.} \end{array}$$

Technically a solution of phenates in water is known as carbolate. It should be clearly understood that the caustic soda lye does not dissolve in the crude naphtha, but during the agitation both the lye and the crude naphtha are reduced to small globules and are thus brought into intimate contact, and while this condition exists the caustic soda in the lye removes the phenols from the oil by combining with them.

After the requisite quantity of lye has been added to the crude naphtha (which amount varies according to the tar acid or phenol content) agitation, which must be gentle, is commenced and continued for some time. The contents of the washer are then allowed to remain at rest in order that a separation of the carbolate from the crude naphtha may take place. The carbolate settles to the bottom of the washer and is removed via the outlet valve, and passing through the separator is conducted to a storage tank by means of a pipe. The object of allowing the carbolate to pass through a separator is to prevent any crude naphtha, which may escape through the outlet valve, from getting into the carbolate storage tank. The method used for the recovery of the tar acids, or phenols, from this carbolate will be dealt with in another chapter. While the carbolate is being removed from the crude naphtha, a sample of the latter is undergoing a test in the chemical laboratory to see if there are any more tar acids in it. If any are found it is washed again with caustic soda lye, the amount required for this purpose being worked out by the chemist or works manager.

When the crude naphtha is free of tar acids it is submitted to distillation in a specially constructed still. The object of this is to remove from the crude naphtha the greater part of the benzol in a crude state. A word of explanation is necessary here. Crude naphtha is a mixture of many definite chemical substances such as carbon disulphide, benzene, toluene, the three xylenes, mesitylene, and so on. These substances possess boiling points as follows: carbon disulphide, 46° Cent.; benzene, 80·36° Cent.; toluene, 111° Cent.; ortho-xylene, 143° Cent.; meta-xylene, 139·8° Cent.; para-xylene, 138° Cent.; mesitylene, 163° Cent. On this account crude naphtha has no definite boiling point, but will commence distilling at about 46° Cent., and the

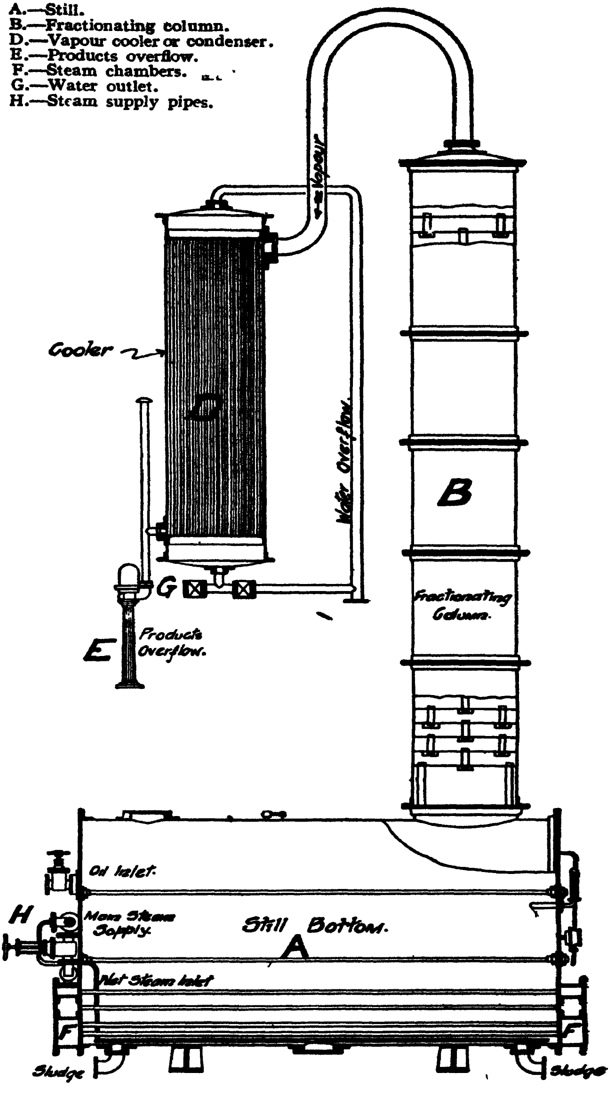

FIG. 14. PRIMARY FRACTIONATING STILL
R. & J. Dempster, Limited

temperature will rise gradually until the whole volume taken has distilled over. If the distillation is stopped at a point round about the temperature of 140° Cent., then that portion, or fraction, of the crude naphtha which has distilled off will constitute crude benzol. The chief ingredients of crude benzol are carbon-disulphide, benzene, toluene and the three xylenes.

As already stated, the washer is erected above the ground level, and this allows the workman to run the washed crude naphtha into the still (*see* Fig. 14), which is on the ground, by force of gravity. The still consists of two chief parts, the body which is cylindrical in shape and made of mild steel plates tightly riveted together, and the column, which is a narrow cylinder containing a number of perforated plates. The body of the still into which the crude naphtha is run is erected in a horizontal or vertical position, and is provided with an inlet pipe through which the still is filled, an outlet valve or cock through which the residue, after distillation, known technically as "bottoms," is removed, an outlet on the top which is connected to the bottom of the column and through which the vapours from the crude naphtha in the still pass to enter the column, a manhole fitted with a tight cover, the purpose of which is to allow men to enter the still in order to carry out cleaning or repairing operations, a safety valve, a glass gauge by which the still-man can see the height of the charge of crude naphtha in the still, a series of tubes of small diameter into which steam is passed for the purpose of heating the crude naphtha (these are fitted in the bottom portion of the still) and a perforated steam pipe, which is also placed on the bottom of the still and through which steam is blown into the crude naphtha at one part of the operation in order to assist the distillation.

As previously mentioned, the column contains a number of perforated iron plates, and these are arranged one above the other at equal distances apart, and are supported upon iron brackets. At the top of the column is an outlet through which the vapours distilling off from the crude naphtha escape and pass into a pipe which leads them to a condenser coil.

As soon as a full charge of crude naphtha is in the still, steam is turned into the steam tubes and the temperature of the naphtha raised gradually. After a time vapours arise (the distillation has commenced) and these vapours will pass through the outlet on the still top into the bottom of the column. As the mixed vapours travel up the column and through the perforations in the plates the higher boiling substances contained in them will, owing to the comparatively low temperature of the column, return to the liquid state (become condensed), and part of this liquid will remain on the surface of each plate, the balance running through the holes. Fresh vapours, as they rise in the column, pass through the holes and thus come into intimate contact with the liquid which is running in the opposite direction. This state of affairs causes condensation of the higher boiling substances in the vapours, only the lower boiling substances passing on. Also some of the higher boiling materials are removed from the ascending vapours by the liquid as it falls from plate to plate. The liquid eventually finds its way into the still through a pipe connected to the first section of the column, and which extends nearly to the bottom of the still. The action taking place in the column is called fractional condensation, and the entire process, viz., continuing to heat the naphtha to convert it into vapours and the partial condensation of these vapours in a specially constructed column, allowing the lower boiling substances to pass forward to a condensing coil in which they are condensed, is called fractional distillation.

At the commencement of the distillation the lighter materials are driven off from the crude naphtha with comparative ease and very little steam is required, but as the process progresses the steam supply has to be increased from time to time, as it is necessary to raise gradually the temperature of the still contents in order to obtain a continuous flow of vapours from the still and through the column. In many cases it is possible to conduct the entire distilling operation by means of steam passing through the tubes, but sometimes it becomes necessary, towards the end of the operation, to introduce a little steam into the still through the perforated steam pipe. The introduction of steam in this manner has to be carried out with care, and the object of its introduction is to assist the distillation of the higher boiling substances. The vapours on leaving the top of the column, are led, by means of the vapour pipe, into an iron condenser coil, which is placed in a mild steel tank and there surrounded by cold water. During the distilling operation the water is allowed to flow slowly through the tank, and in its progress it absorbs heat from the vapours as they pass through the coil and thus cause them to condense. From the end of the condenser coil the distillate (condensed vapours) runs into a small iron vessel called a divider, which, by a special arrangement of pipes, serves the purpose of separating any water which comes with the distillate. During the first portion of the distilling operation, when open steam is not employed, no water comes over, and the pipes in the divider are so arranged that the one which carries away separated water is thrown out of action. The distillate on leaving the divider, is led to an iron tank called a receiver.

At a point, which is arranged by the works manager, the distillation is discontinued. As will be noted from a description of the still, a thermometer is not attached to it, and on this account the control of the distillation and the finding of the point at which it is stopped cannot be carried out by temperature observations. This point is decided by carrying out a distillation test, in the chemical laboratory, on the material in the receiver after well stirring, and also occasionally taking the specific gravity of the distillate as it leaves the condenser coil.

The distillate worked off the crude naphtha is called technically "once-run benzol," and it is from this material that the several grades of benzol and toluol, and also some solvent naphtha, are obtained. The working up of "once-run benzol" will be dealt with later on.

The residue in the still, known as "bottoms," is sometimes run out into a storage tank, and when a sufficient quantity has accumulated it is submitted to a special distillation, or it is allowed to remain in the still, and on to it is run a charge of "once-distilled" light oil.

Once distilled light oil is prepared from virgin light oil (that is light oil in the state in which it is obtained from coal tar) by submitting it to distillation after it has been washed several times to free it from tar acids. Caustic soda lye is used to wash the oil, and the process is the same as that described when dealing with crude naphtha, see page 49. After the final wash the oil is allowed to settle for some time in order that any entangled carbolate may separate. The clear oil is then run into a fire or gas-heated still built of mild steel plates, and which is very similar in construction to a tar still. It has fitted upon it a swan-neck to conduct the vapours to a condenser coil, an inlet for charging purposes, a run-off pipe through which the bottoms are discharged, a safety valve, and a manhole and lid. The condenser coil is connected to the swan-neck, and it is placed in an iron tank so that it can be surrounded by water. The end of the condenser coil is fitted to an inspection chamber to enable the still-man to remove samples of the distillate for testing purposes and to judge of its rate of flow. From the inspection chamber, the distillate known as " once-distilled light oil " runs into a receiver.

A receiver is constructed of mild steel plates, and is provided with a coil of steam-pipe which is laid on the bottom. It has on the top a manhole and lid, an inlet for the insertion of a distillate pipe, and an outlet hole through which is passed the suction pipe of a pump. The object of the steam coil is to enable the still-man to raise the temperature of the once-run light oil, because, in the majority of cases, when it cools down to the ordinary atmospheric temperature, a certain amount of naphthalene salts crystalize out, and a large quantity of these would remain in the receiver when it becomes necessary to remove the oil.

The still-man must be quite certain that the carbolate has been properly separated from the light oil before he charges the still with it, otherwise trouble may arise during the earlier part of the distilling operation. It is, however, not possible to free the light oil entirely from carbolate, and on this account the charge in the still must be heated carefully at first in order to prevent boiling over, or " priming," as it is termed in the tar distillery.

During the first part of the operation the water contained in the carbolate comes over with the distillate, and until this discontinues it is a very risky procedure for the still-man to employ a big fire. Immediately the water stops, the intensity of the fire is increased, and this is done from time to time in order that the distillate will come over evenly and in a fairly rapid stream. It is necessary to allow the water in the condenser tank to become hot in order to prevent the formation of crystals of naphthalene salts in the condenser coil. If crystals do form in sufficient quantity to choke the coil there is a risk of an explosion occurring, especially if the safety valve by any chance fails to act. All the time the light oil is being heated vapours are given off from its surface, and if these cannot escape via the swan-neck and condenser coil on account of the choking of the latter, then the pressure inside the still will gradually increase until the shell of the still cannot withstand it.

The point at which the distillation is finished varies a good deal according to the type of light oil under treatment, and it is decided by the works chemist who, acting under instructions received from the works manager, carries out tests in the chemical laboratory. From the results of these tests a certain specific gravity is given to the still-man, and when the distillate as it leaves the coil end, shows this specific gravity the operation is brought to a close.

The idea of distilling the light oil in the manner just described, before working it up for the naphthas, is to remove a great deal of the naphthalene, and also the oils which possess high boiling points and which could not possibly be sold as naphthas. If the light oil was washed with the naphthalene and high boiling substances in it, it would mean a considerable loss of washing material and naturally add to the expense of production of the finished articles.

The once-run light oil is removed from the receiver by a pump and charged into a washer and there washed with caustic soda lye to remove the small quantity of phenols which it contains. After the washing it is allowed to remain at rest for the carbolate to settle to the bottom of the washer, and the carbolate is then run off to its storage tank. A further period of time is allowed in order to allow any carbolate, which may still remain in the oil, to separate, and these drainings are run to the carbolate storage tank via the separator, which piece of apparatus will prevent any oil getting into the carbolate storage tank.

The completely washed and drained once-run light oil is then run into the still (*see* Fig. 14) which contains the crude naphtha bottoms, or else into a clean still, according to circumstances. Here it is heated by the passage of steam through the steam tubes, care being taken not to heat too strongly at first in order to prevent priming. In this case priming would cause considerable trouble, because the undistilled once-run light oil would get into the column of the still, and it would be necessary for a large quantity of vapours to pass through the column to " wash " it out before distillation proper could be proceeded with.

When the still-man sees oil appearing at the end of the condenser coil, he will raise the temperature of the still contents a little, and manipulate the steam supply so that a steady flow of distillate is secured. After a while the rate of distillation slackens although the temperature in the still remains high, and at this point it is necessary for the still-man to introduce steam into the still contents through the perforated coil in order to assist the higher boiling point substances to distil over. Water and oil will now appear at the condenser coil end, and this will necessitate the mixed distillate flowing through the separator, which has already been described, in order to separate the water from the oil automatically. As a rule the water is run to waste, but in some works it is used on the pyridine plant. Distillation under these conditions is continued until a sample of the oil, free from water, answers a prearranged test when examined in the chemical laboratory, and at this point the operation may be brought to a finish or may be continued, but allowing the distillate in the latter case to flow into another tank.

The oil which has already been collected is known as "once-run naphtha," and if the distillation is continued the second fraction is known as "once-run heavy naphtha." The once-run heavy naphtha fraction will contain a certain amount of naphthalene, and the distillation is brought to a close before this substance appears in the distillate in large quantities. During the latter part of the distilling operation the water in the condenser tank is allowed to get warm to prevent the formation of crystals of naphthalene in the condenser coil. The residue in the still is allowed to remain at rest for a short time in order to cool a little, and is then run off into a "bottoms" receiver. This receiver is provided with a steam coil in order to raise the temperature of the contents, because at ordinary temperatures the "bottoms" set solid. From time to time these "bottoms" are removed and mixed with certain qualities of creosote oil, or else used for the preparation of naphthalene.

CHAPTER VI

THE next stage in the manufacture of benzols and naphthas is the removal of the impurities contained in the once-run benzol, once-run naphtha, and once-run heavy naphtha. These impurities consist chiefly of traces of tar acids, pyridine bases, unsaturated hydrocarbons, and carbon disulphide. The first impurity is removed from the materials under consideration by washing with caustic soda lye, and with the exception of the last named, the balance is removed by washing or agitating with sulphuric acid.

The type of washer used for the removal of tar acids has already been described. (See page 48, Chapter V.).

Washers employed in the process of removing pyridine, etc., are constructed of cast iron, and they are often lined with lead. They are cylindrical in shape with a conical bottom to which is fitted a special acid-resisting cock or tap. Inside the washer is fitted an agitator, which consists of an iron shaft upon which arms are fixed. The position of the agitator varies; in some washers it is vertical and in others horizontal, but in all cases it is mechanically driven. The top of the washer is generally covered in, and in many cases with wood. An opening is provided in the cover through which the benzol or naphtha charge-pipe enters, and in some plants a lead pipe is also put through the cover for the purpose of leading into the washer the two grades of sulphuric acid, used in washing the oils, from their respective lead-lined supply tanks. There is also a large hole in the cover through which the benzol plant-man manipulates his water supply, the purpose of which will be explained shortly. The washer is erected above the ground-level, and it is fitted with a suitable stairway and staging so that the workman can carry on his work in safety.

Dealing with once-run benzol first: This is tested in the chemical laboratory to see whether it is free of tar acids. If this is not the case it is washed with a little caustic soda lye in a tar acid washer and allowed to settle for some time, as already described. (See page 50.) The lye which settles out, and now contains some tar acids, is conveyed by a pipe to the carbolic plant for further use, and the tar acid free once-run benzol is allowed to flow or is pumped into the acid washer. As soon as sufficient benzol has been charged into the washer the agitator is started and a small quantity of strong sulphuric acid, known technically as B.O.V., is added slowly. When all the acid has been added agitation is continued for some time, and then the contents of the washer are allowed to come to rest, and after a further interval the acid liquor which separates out and settles to the bottom of the washer, called pyridine acid, is run through the cock into a lead-lined tank situated close by. In many works a small quantity of dilute B.O.V. is now added to the once-run benzol while it is being agitated, and after continuing the agitation for a short time the acid liquor (dilute pyridine acid) is allowed to settle out and then run into the pyridine acid tank.

After the removal of the dilute pyridine acid the agitator is started again, and a small portion of very strong sulphuric acid, known as D.O.V., is added slowly. Agitating the once-run benzol with the D.O.V. is continued for some time, but care is taken not to overdo it as the acid substance, termed acid-tar, when it settles out, may set solid. When the time allowed for agitation has elapsed, the contents of the washer are allowed to settle for a while and the thick acid liquor, which falls to the bottom of the washer, is run into the acid-tar tank for treatment. A further period of time is allowed for draining and any more acid-tar which separates is run off. It should be mentioned here that in some works the acids are not supplied to the washer from lead-lined tanks via the lead-supply pipe previously referred to, but they are tipped out of glass carboys, which hold about 10 gallons of acid, and which are enclosed in iron baskets lined with straw, into the washer through a large hole in the cover. This method is a rather dangerous one, and none but a careful workman should be entrusted to carry out the operation. The removal of the pyridine bases from the once-run benzol and once-run naphthas by sulphuric acid is made possible by the fact that pyridine and its homologues (known collectively as pyridine bases) possess the power of combining with acids to form substances termed salts. Sulphuric acid is the most suitable acid to use in the case under consideration, and the reaction which takes place is represented by the following chemical equation—

$$\begin{array}{ccccc} 2\ C_5H_5N & + & H_2SO_4 & = & (C_5H_5N)_2H_2SO_4 \\ \text{Pyridine} & + & \text{Sulphuric} & = & \text{Pyridine sulphate.} \\ & & \text{Acid.} & & \\ \text{(Two molecules.)} & & \text{(One molecule.)} & & \text{(One molecule.)} \end{array}$$

Pyridine sulphate and the sulphates of the homologues of pyridine are soluble in water and also in dilute acid.

The hydrocarbons which constitute once-run benzol and the once-run naphthas are not readily attacked by sulphuric acid of the B.O.V. strength, but in the case of very strong sulphuric acid (D.O.V). it is different, and it has to be used with care. The object of washing with D.O.V. after the B.O.V. is to remove those impurities in the benzol and naphthas which come under the head of unsaturated hydrocarbons. Very strong sulphuric acid possesses the power of dissolving, or resinifying these compounds.

The next part of the process is to wash the once-run benzol with water in order to remove traces of acid-tar. In the first instance, water is sprayed by means of a hose over the surface of the benzol and down the sides of the washer. After a certain quantity has been added in this fashion, the supply of water is cut off and a short time allowed to elapse to enable it to fall to the bottom, when it is run off through a separator into a neutralizing tank and then to the drain. The agitator is now started, the contents of the washer brought into violent motion, and more water added. This process is continued for several minutes, after which the mixture is allowed to rest, and the water which drops to the bottom run off and treated in the manner just described. When the once-run benzol has been washed two or three times with water a little dilute caustic soda lye is added to it while it is being agitated. This is done with the object of rendering the benzol free from acid to prevent it exerting a corrosive action on the still into which it is eventually charged. In some of the best works, a separate washer is used for the caustic soda lye treatment, but if the water-washing is carefully done this is not absolutely necessary.

In the case of once-run naphtha, the washing processes are essentially the same, but the amount of acid used is sometimes increased. The same remarks apply to the once-run heavy naphtha. In some works the once-run naphtha, and particularly the cnce-run heavy naphtha, are put through a further distillation before they are washed with acid. The object of this is to remove some of the naphthalene and very high boiling substances which are present in these materials. This not only effects an economy in the use of the acid, but also decreases the loss of material through washing and it also results in a better quality of finished material.

CHAPTER VII

THE washed once-run benzol, once-run naphtha and once-run heavy naphtha are split up into benzols and naphthas by distillation in a specially constructed still (*see* Fig. 15), to which is attached a fractionating column and a piece of apparatus called a dephlegmator. The still is cylindrical in shape, and is built of mild steel plates, the joints being tightly riveted in order to avoid leakage. It is placed in a horizontal position, and is supported upon cradles of cast iron or brickwork. At the bottom are two outlets—one at each end—upon which are fitted cocks or valves and through which the residue, left after distillation, is released into pipes which conduct it to a receiver. On the ends of the still are fitted two cast-iron boxes, known as steam chests, and these are connected by a number of tubes which are placed inside and along the bottom of the still. The object of the steam chests and tubes is to divide the closed steam supply in such a way that the benzol or naphthas are heated to the temperature of distillation in a rapid and economical manner. In addition to the tubes, a length of perforated pipe is laid upon the bottom of the still through which steam can be blown direct into the once-run benzol or once-run naphtha. At one end of the still is fitted a glass gauge by means of which the still-man can see the level of the still contents, and at the other end, near the top, is an inlet valve through which the oil is supplied to the still. A manhole, which is provided with a tightly-fitting lid (the use of which is to allow a workman to get inside to inspect the still and to carry out repairs), a safety valve, and a casting upon which is erected a fractionating column, are fitted on the top of the still.

The fractionating column consists of several cast-iron sections, cylindrical in shape, in which are suspended a number of perforated iron plates. These plates are fitted with drip-pipes and cups, which are so arranged that they cause a seal of liquid to remain on each plate during the working of the still. There is another type of column in which the sections are much smaller and each section contains one plate only. Each plate is fitted with a seal-pipe, a vapour inlet and a disperser hood. The hood is placed over the top of the vapour inlet, and as its edges are serrated, the vapours, on leaving the inlet, must necessarily pass through the seal of liquid on the plate through the serrations of the hood.

At the top of the fractionating column is fitted a pipe which leads the vapours into what is termed a dephlegmator. This piece of apparatus consists of a number of very small tubes held in position by a perforated plate at each end and enclosed in an iron cylinder. Water is caused to flow through the tubes, and the vapours from the fractionating column pass round the tubes. The outlet of the dephlegmator is connected up by means of a pipe to a condensing coil, similar in design to that described on page 10, or of the tubular type. The tubular type of condenser is very similar in construction to a dephlegmator, there being a number of small tubes enclosed in an iron cylinder.

The condensed vapours, as they leave the condenser, are conducted, via a separator, into receivers, which vary in shape, some being rectangular, others cubical, and others cylindrical. The object of the separator is to remove automatically the condensed steam which comes over towards the end of the once-run benzol distillation and when the once-run naphthas are being distilled.

A.—Still.
B.—Fractionating column.
C.—Analyser or dephlegmator.
D.—Vapour cooler or condenser.
E.—Products overflow.
F.—Steam chambers.
G.—Water outlet.
H.—Steam supply pipes.

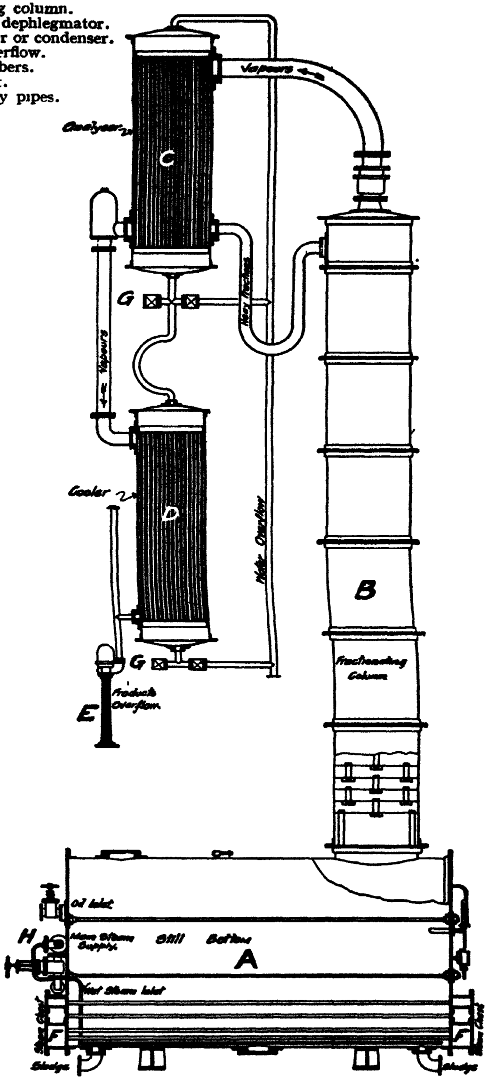

FIG 15. FINAL FRACTIONATING STILL
R. & J. Dempster, Limited

From once-run benzol is prepared 90^s benzol and sometimes a distillate known as $50^s/90^s$ benzol. The meaning of these terms is as follows: 90^s benzol is a material which, if distilled in a piece of glass apparatus called a retort, will yield 90 per cent. of its total volume when a thermometer, the bulb of which is immersed in the liquid, indicates 100° Cent., and a $50^s/90^s$ benzol is one which, if distilled in a similar apparatus, will yield 50 per cent. at 100° Cent. and 90 per cent. at 120° Cent.

In commencing a distilling operation the still is charged to about two-thirds full with washed and well drained once-run benzol, and steam is then passed through the tubes via the steam chest. The still contents are heated gradually to prevent boiling over or priming. If this unfortunately occurs, the fractionating column will become filled with the washed once-run benzol, and this will involve a considerable amount of trouble in the way of clearing the column before distillation can be proceeded with. As soon as the still-man observes a small quantity of liquid running from the end of the condenser coil the temperature is increased a little, and this has to be repeated from time to time in order to keep up a steady flow of distillate.

The first portion of the distillate contains a large quantity of carbon disulphide, and it goes by the name of benzol fronts. It is allowed to run into a special receiver and is dealt with in a variety of ways according to conditions existing in the works. When the fronts have distilled off the flow of distillate is directed into another receiver with the intention of preparing 90^s or $50^s/90^s$ benzol. Occasional samples of this distillate are collected as it comes away from the condenser, and are examined in the chemical laboratory. When the chemist finds that it answers a pre-arranged test, the still-man either discontinues the distillation or shuts the tap upon the pipe which is leading the distillate into the 90^s benzol tank and opens the tap on another pipe which leads to a separate receiver.

In the manufacture of 90^s and $50^s/90^s$ benzol, it is not necessary to blow steam into the still contents through the perforated pipe, and as this means that no water comes over with the distillate the separator is not put into use.

Throughout the distillation the vapours which arise from the boiling once-run benzol pass upwards into the fractionating column and the lower boiling portion of these vapours leaves the column at the top and enters the dephlegmator; the higher boiling portion being condensed. The object of the dephlegmator is to carry out, on a rather more elaborate scale, the process which goes on in the fractionating column and which has already been described on page 53. The water which passes through the tubes of the dephlegmator condenses the higher boiling vapours and allows the lower boiling ones, which consist chiefly of benzene and toluene, to pass onward to the condenser in which they are brought to the liquid state. All the condensed higher boiling vapours are returned to the still from the column and the dephlegmator via seal pipes.

When the distillation of the once-run benzol is completed, the still-man thoroughly mixes the contents of the receiver, takes a sample, and a further test is carried out on this sample in the chemical laboratory to ensure that it answers the requirements of a 90^s, or a $50^s/90^s$ benzol. If this is not the case adjustments are often made from material already in stock, adding the calculated quantities and well mixing.

Toluol is manufactured from washed once-run benzol by distilling off the benzol fronts and then a portion of the purer material. From this point the distillate is run into a receiver until a sample taken from the contents, after well mixing, when tested in the chemical laboratory gives the figures required for a commercial toluol. When distilled in a retort in a similar manner to that described on page 68 for benzol, commercial toluol should yield 90 per cent. of its volume at a temperature of 120° Cent.

The residue in the still is sometimes allowed to cool and then run off into a storage tank for further treatment, or else the washed once-run naphtha, after thoroughly draining, is charged on to it. As soon as the charging of the still is completed, steam is passed into the tubes and the still contents are heated up gradually in a similar fashion to that described for the distillation of benzol. The distillation will progress for some little time at a steady rate, and will then gradually slacken off. At this point the still-man will introduce steam through the perforated pipe at the bottom of the still in order to assist the distillation of the heavier boiling substances (steam distillation is resorted to). This results in water as well as oil leaving the end of the condenser coil, and, therefore, the separator is put into use. The water which separates automatically is run into a catch pit, and from this piece of apparatus to the drain. The object of the catch pit is to prevent the oil, which may be carried away from the separator, from running to waste; it rises to the surface of the water in the catch pit and is skimmed off from time to time.

The condensed naphtha vapours, as they leave the separator, are run into the receiver. From time to time the still-man collects a sample of the water free distillate, and determines its specific gravity, and occasional samples are sent along to the chemical laboratory to be submitted to a distillation test by the chemist. When a test gives a result which indicates that the solvent naphtha fraction has been distilled off, the still-man will divert the flow of distillate as it leaves the separator, from the 90 per cent. at 160° Cent. solvent naphtha receiver to the heavy naphtha receiver by manipulating cocks. Usually the distillation for heavy naphtha is continued until the still is almost empty, and both the steam supply to the tubes (closed steam), and also that to the perforated pipe (open steam) are increased as the operation progresses.

There are several qualities of naphtha manufactured, the chief of which is that known as 90 per cent. at 160° Cent. This term means that if a given quantity of the naphtha is distilled in a glass retort, the bulb of the thermometer being immersed in the liquid, it will yield 90 per cent. by the time a temperature of 160° Cent. is reached. There are other qualities of solvent naphtha, such as 90 per cent. at 165° Cent., and also qualities which flash above 73° Fahr. Abel's close test, and these are made by altering the point at which the oil, as it leaves the separator, is diverted from one receiver into another. The small amount of residue left in the still is run out while hot into a bottoms tank, and is worked up later for naphthalene, or else mixed into creosote oil.

From the once-run washed heavy naphtha special heavy naphthas are prepared. The washed product is charged into the still, and after it is heated by means of closed steam, open steam is introduced gradually and the coil end watched carefully until water and naphtha make their appearance. The supply both of closed and open steam is then regulated so that a steady flow of water and naphtha pass through the divider. The point at which the distillation is discontinued is determined by the chemist in the manner just described, but the test figures will vary according to the quality of heavy naphtha required. There are several qualities of heavy naphtha manufactured, one which flashes at about 100° Fahr., Abel's close test, and possesses a specific gravity of about 0·925, and another which will yield, on distillation in a retort, about 60 per cent. at 190°Cent.

The physical properties and the constitution of the products which have just been dealt with are given in table—

Name.	Per cent. of Pure				Specific Gravity at 15·5° Cent.	Colour.
	Benzene	Toluene.	Xylene	Cumene.		
90s Benzol	84	13	3	—	0·880 to 0·883	Colourless
50s/90s Benzol	43	46	11	—	0·875 to 0·878	,,
Toluol	15	75	10	—	0·870 to 0·873	,,
Solvent Naphtha 90%, at 160° C.	—	5	70	25	0·874 to 0·878	,,
Heavy Naphtha	—	—	5	80	0·920 to 0·948	Colourless to pale straw, sometimes port-wine colour.

By far the greater quantity of benzol manufactured is employed in the preparation of commercially pure benzene, the uses of which will be dealt with briefly in another chapter.

Solvent naphtha is used largely in the india-rubber, mackintosh and waterproof sheet industries; it is an excellent solvent for india-rubber. Special grades of solvent naphtha are used as naphthalene solvents in the gas industry.

In the paint and varnish industry the heavy naphthas find application as solvents, entering into the composition of cheap rosin varnishes, black varnishes, compositions for ships' bottoms and anti-corrosive paints. Certain qualities are also employed as burning oils.

During the last few years benzol has been largely used as a motor fuel, and a few words in regard to this matter will no doubt prove of interest to the reader. It is necessary that the benzol used for this purpose be pure, and 90^{s} benzol is the best quality to use. The crude product from which it is made must be properly washed with acid, water and alkali, and carefully distilled in order to free it from various impurities, particularly the sulphur compounds, the chief of which is carbon disulphide. Sulphur compounds on combustion first form sulphur dioxide, and this substance is then converted into sulphurous acid by the water vapours present. This acid is, in its turn, oxidized to sulphuric acid, which will attack the cylinder and valves and so cause corrosion.

Benzol, if anything, is vaporized a little more easily than petrol, and furthermore, as it is a far more homogeneous mixture than petrol, the bulk of it will volatilize away at a more constant rate. In other words, about 25 per cent. of the bulk of petrol distils above the temperature at which all the benzol has been vapourized.

Experience has shown that it is possible to start a motor engine when cold on 90^{s} benzol, providing, of course, it is up to quality. It has been found in use that engines driven by benzol run smoother and that more milage is obtained per gallon; for instance, there is practically an increase of five miles per gallon in favour of benzol when compared with petrol. The following figures will explain this fact—

	Calorific value of 1 lb. in B.Th.U. (*a*)	Weight of 1 gall. in lbs. (*b*)	Calorific value of 1 gl. in B.Th.U. (*a*) × (*b*)	Balance in favour of Benzol.
Benzol	17,780	8·8	156,464	10,304
Petrol	20,300	7·2	146,160	

Benzol is used very largely as a motor fuel when mixed with petrol. It is necessary, however, to call the attention of the reader to the fact that benzol cannot be used as a fuel for aeroplane engines as it crystallizes at low temperatures and would bring about choking of the feed pipe, which, as will be readily understood, would place the pilot of the aeroplane in difficulties.

The annual production of benzol varies. For instance, the quantity manufactured in 1928 amounted to 1,960,668 gallons, whilst that in 1929 was 2,150,918 gallons. These amounts do not include benzol recovered from coke oven tar.

CHAPTER VIII

In the manufacture of a great number of coal tar colours and also some of the artificial drugs and synthetic chemicals, it is necessary to employ almost chemically pure benzene, toluene and xylene. These products are prepared in very large quantities from the best qualities of 90^{s} benzol, toluol and xylol respectively. In the manufacture of pure benzene 90^{s} benzol is the starting-point and, as has already been shown, this substance consists of a mixture of benzene, toluene, and xylene, and traces of certain impurities such as carbon disulphide and thiophene. It is necessary, therefore, to submit the 90^{s} benzol to certain processes in order to separate the toluene and xylene, and also the impurities. In regard to the toluene and xylene and also the impurity carbon disulphide, these can be removed by the process of fractional distillation, but as the other impurity, thiophene, boils at a temperature approximately the same as that at which pure benzene does it has to be taken out of the benzol by chemical treatment.

One method of preparing commercially pure benzene is as follows: A pre-determined volume of a first-class quality of 90^{s} benzol is charged into a lead-lined washer provided with a mechanically-driven agitator, a run-off cock, etc., similar to the washer described on page 60, and it is agitated thoroughly a number of times with small quantities of a very strong sulphuric acid. After each agitation the benzol is allowed to rest and the acid liquor, or acid-tar as it is called, precipitates to the bottom of the washer and is carefully run off into a receiving tank. Strong sulphuric acid has the power of dissolving the thiophene whereas, providing the temperature of the contents of the washer is not allowed to rise very high, the benzol is not attacked to any great extent. After several acid washings have been given, the benzol is tested in the chemical laboratory, and if it answers the necessary test the benzol is then washed with water. The first one or two water washes are carried out without agitation, the water being sprayed over the surface of the benzol and down the sides of the washer, but in the balance of the water washes gentle agitation is resorted to. When the water which settles out is practically free from acid, a wash is given with a dilute solution of caustic soda, and then generally a further wash with water. After the final washing the benzol is allowed to drain thoroughly, and is then charged into a fractionating still (Fig. 15) similar in construction to that used for the manufacture of 90^{s} benzol. Often there are a few more plates in the fractionating column and the dephlegmator is somewhat larger.

The still contents are very gently heated with closed steam and the distillation is carried on slowly, great care being taken to prevent priming. Samples are taken from the receiving tank from time to time and tested in the chemical laboratory, and the distillation is stopped as soon as a sample of the well-mixed contents of the receiver commences to boil at the correct temperature when tested in a glass retort. The point at which commercially pure benzene begins to boil is about 80·5° Cent., and at least 90 per cent. of its bulk should distil over within 1° Cent.

The residue in the still will contain a considerable amount of toluene, and this material is used for the manufacture of commercially pure toluene. In some cases the residue is mixed with commercial toluol, and in *every case*, in order to remove impurities, the mixture is agitated in a washer with strong sulphuric acid containing a small portion of nitric acid, and in most instances this acid mixture is used hot. Washing with water and caustic soda solution follows the acid washing in a similar manner to that used in the manufacture of commercially pure benzene, and the washed and well drained toluol is submitted to careful fractional distillation, the contents of the receiving tank being tested from time to time as already explained, until a test shows the correct boiling point, etc. Usually commercially pure toluene begins to boil at 111° Cent. and yields about 95 per cent. of its volume within 1° Cent.

In the manufacture of commercially pure xylene commercial xylol is employed, and this material is often mixed with the residue left in the still from the preparation of toluene. The process used is similar to that described for toluene both in regard to washing and distillation. Commercially pure xylene should begin to boil at about 136° Cent. and yield about 95 per cent. of its volume within 3° to 4° Cent. Note should be made of the fact that commercially pure xylene is not a definite chemical substance, but it consists of a mixture of ortho- meta- and paraxylenes.

If it is desired to manufacture either extra pure benzene, toluene or xylene, commercially pure benzene, toluene or xylene is submitted to a very careful refractionation in a still provided with an efficient fractionating column and dephlegmator.

Pure benzene is a very important raw material employed in the manufacture of coal tar colours, some synthetic drugs and artificial perfumes, and its value as a commercial asset is very considerable. The significance of this remark will be made evident by the following—

Benzene, if acted upon by nitric acid in the presence of sulphuric acid, yields a pale yellow oil called *nitrobenzene*. This substance smells something like essential oil of almonds, and it is used under the name of " essence of mirbane " as a perfume for soaps. Its chief use, however, is for the manufacture of *aniline*. Aniline is prepared by acting upon nitrobenzene with scrap iron and hydrochloric acid, and when pure it is a colourless oil which gradually turns yellow on exposure to light. If aniline is boiled with glacial acetic acid, *acetanilide* (antifebrin), a drug used in the treatment of neuralgia and certain fevers, is formed. On the other hand, if aniline is heated with methyl alcohol and hydrochloric acid a substance called *methyl aniline* results, and if this material is acted upon by acetyl chloride a drug which goes by the name of *exalgin* is formed. This drug is sometimes used in the treatment of neuralgia. Again, commencing with aniline, if it is dissolved in hydrochloric acid and carefully acted upon by a solution of sodium nitrite in water, diazobenzene chloride results, and this material, when treated with a reducing agent, yields phenylhydrazine hydrochloride from which phenylhydrazine is recovered. On treating this substance with ethyl aceto-acetate, and the resulting product with methyl iodide, the drug *antipyrine* is formed. This drug is used for the treatment of rheumatism, neuralgia, migraine, and many other painful affections. The very valuable drug *atoxyl*, which is used in the treatment of sleeping sickness, is prepared from aniline.

Again, starting with benzene, this is nitrated and the nitrobenzene formed is converted into *benzidene* by acting upon it with zinc dust and caustic soda and treating the resulting product with water and hydrochloric acid at 100° Cent. From benzidene many *azo colours* are prepared, and among these are Congo red, Congo corinth, diamine violet, diamine brown, diamine scarlet, diamine blue, diamine black and benzo-orange. The methods used in the manufacture of these dye stuffs are very involved, and those readers who are interested in the dye-stuffs are referred to the special works on these materials.

As will be seen from the " family tree " (Fig. 16) many other coal tar dye-stuffs have their source in benzene, nitrobenzene, aniline, diphenylamine, etc., being the intermediate products.

From *benzene*, through meta-dinitrobenzene, a *brown dye* (Bismark brown) is obtained, and meta-dinitrobenzene enters into the composition of some of the *flameless explosives.*

Although very large quantities of carbolic acid (phenol) are obtained from coal tar distillates by methods of washing, distillation and crystallization, there are times when a considerable amount is prepared from benzene by what is termed the method of synthesis. Briefly the process is as follows: *Benzene* is boiled with an equal volume of concentrated sulphuric acid and the resulting *benzene monosulphuric acid* fused with caustic soda. The sodium phenate formed is decomposed with mineral acid and the phenol which separates purified by recrystallization.

Toluene is the source of many coal tar colours, also some synthetic drugs and artificial perfumes, and the high explosive *tri-nitro toluene* or T.N.T. If *toluene* is acted upon by chlorine gas *benzal chloride* or *benzyl chloride* is formed according to the amount of chlorine allowed to combine with the toluene. Benzyl chloride is used in the preparation of *benzyl violet*, and if benzal chloride is heated with lime and water under pressure *benzaldehyde* results. This material is employed in perfumery and as a flavouring agent under the name of *artificial essential oil of almonds*. Benzaldehyde is used in the preparation of *Malachite green*, and, after nitration, in one of the processes for the manufacture of *artificial indigo*. Toluene is also one of the raw materials used in the preparation of the coal tar colour *magenta*. The sweetening agent *saccharine*, artificial *musk* (a perfume), and *beta-eucaine*, which is used as a local anaesthetic in dentistry and many branches of surgery, are all manufactured from toluene.

CHAPTER IX

It will be remembered that in the process of washing once-run benzol and once-run naphtha with sulphuric acid, a substance was obtained which was called pyridine acid. It is from this material that pyridine bases and pure pyridine are manufactured. The preparation of pure pyridine does not come within the province of the tar distiller, but in all large distilleries pyridine bases are recovered from pyridine acid.

As already explained, pyridine acid consists chiefly of a combination of pyridine bases and sulphuric acid (sulphates of pyridine and its homologues) dissolved in water, and in order to recover the pyridine it is necessary to decompose this combination, fixing the sulphuric acid and setting free the pyridine bases. This is done as follows: The pyridine acid is run into a large lead-lined tank and diluted with a considerable amount of water, agitating from time to time during the addition of the water. The contents of the tank are then allowed to rest for some time when any entangled oily matter will rise to the surface, and this material is removed by skimming, or some other suitable means. While the diluted pyridine acid is resting, a large still made of mild steel, to which is fitted a manhole and lid, a pipe for charging, a pipe for carrying away vapours, a perforated steam coil which rests on the bottom inside, and also a large gate valve on the outside at the bottom, is partly filled with milk of lime.

Milk of lime is prepared by agitating slacked quicklime with cold water, and it has the consistency of milk. The quantity placed in the still is so calculated that there will be some lime remaining after the sulphuric acid, which is contained in the diluted pyridine acid in combination with the pyridine bases, has been converted into a substance known as calcium sulphate. As soon as the charge of quick-lime is in the still, the manhole is closed and the diluted and clarified pyridine acid is charged into the still. This is done carefully as a certain amount of heat is generated, due to the combination of the sulphuric acid with the lime, and if care is not exercised boiling over may take place. The reaction which takes place is expressed by the following chemical equation—

$$\begin{array}{lclclclcl}
(C_5H_5N)_2H_2SO_4 & + & Ca(OH)_2 & = & 2\,C_5H_5N & + & CaSO_4 & + & 2\,H_2O \\
\text{Pyridine Sulphate} & + & \text{Calcium} & = & \text{Pyridine} & + & \text{Calcium} & + & \text{Water} \\
 & & \text{Hydrate} & & & & \text{Sulphate} & &
\end{array}$$

As soon as the whole of the diluted pyridine acid has been charged into the still steam is turned on very carefully. This not only brings about an agitation of the contents of the still but it gradually heats it to a point at which pyridine bases begin to distil off. As pure pyridine is soluble in water, and as this compound comes off at the commencement of the distillation, the vapours, which are condensed in a coil, placed in an iron tank and surrounded by cold water, leave the coil end as a solution of pyridine in water. During the whole of the time occupied by the distillation cold water is run through the condenser tank. After a time more steam is supplied to the still, and the liquid which leaves the condenser coil end is found to be a mixture of oil and water. This is due to the fact that the homologues of pyridine, known as heavy pyridine bases, are not soluble in water, and are being driven off by what is known as steam distillation.

In some works the solution of pyridine in water, which comes over first, is run into one tank and the mixture of water and heavy pyridine bases into another, but generally the whole of the distillate is run into one tank. When the distillation is finished the residue in the still, which consists of a mixture of water, lime and calcium sulphate, is released into a sludge tank, the position of which is underneath the still, by opening the gate or sluice valve fitted on the still bottom. The still is then allowed to cool down, the manhole opened, and the inside washed down with water supplied through a hose pipe.

The next part of the process employed in the recovery of pyridine bases is to separate the pyridine from the water in which it is dissolved, and this is done by adding to the contents of the tank a very strong solution of caustic soda and thoroughly agitating during and after the addition. The contents of the tank are then allowed to rest, when the pyridine and the heavy pyridine bases will rise to the surface of what is now a more or less dilute solution of caustic soda. The layer of pyridine bases is then run off into another tank and the dilute caustic soda solution is transferred to a storage tank for use on the carbolic acid plant, or in some other cases it is concentrated and used again on the pyridine plant.

The separated pyridine bases will contain a certain amount of water, and this has to be removed by the addition of a further quantity of extra strong caustic soda solution with a thorough agitation. After this has been done the pyridine bases which rise to the surface on leaving the contents of the tank at rest, are tested in the chemical laboratory, and if found to contain not more than 4 per cent. of water, are run into a storage tank or other suitable receptacle. In this state the recovered pyridine bases are known as "crude pyridine," and in many cases are sold to the manufacturers of refined pyridine.

In some tar distilleries, however, it is worked up into refined pyridine as follows: The crude pyridine is charged into a small wrought iron still, very similar in construction to a tar still, but it is provided with a short fractionating column. This column usually contains plates of the perforated type, *i.e.*, iron plates perforated with a large number of small holes. The still is heated by a coal fire or by producer-gas, and great care is taken to prevent the distilling pyridine from priming as, if this occurs, the fractionating column will become contaminated with crude pyridine, and then there is a liability of some of this crude material being carried over into the receiving vessels when the still begins to work normally. The vapours from the crude pyridine, in passing up the column, are subjected to fractional condensation as already explained, the heavier vapours being condensed on the plates, and the lighter ones passing upwards and into the vapour pipe fitted at the top of the column. The vapours, which condense in the column, gradually run back into the still while those which have passed into the vapour pipe at the top of the column are conducted into a condenser coil, generally made of lead. This coil is placed in an iron tank, and is surrounded by cold water which continues to flow through the tank during the process of distillation.

The condensed vapours of the lighter pyridine bases leave the end of the condenser coil and are collected, as a rule, in small vessels. Often these vessels are of glass (known as carboys), and they hold about 10 gallons each. The greater part of the contents of the still is worked over into these receptacles, and that remaining, which is known as "bottoms," is run into a bottoms storage tank, and when sufficient has collected the whole quantity is submitted to a special distillation in the pyridine still. Samples are taken from each of the carboys and are submitted to an examination in the chemical laboratory, the works chemist handing his tests to the works manager, who decides how many of these carboys are to be emptied into a larger vessel in order to make a mixture which will answer specifications laid down from time to time.

The heavier pyridine bases are obtained by submitting the "bottoms" to a distillation, or in some cases by carrying on the distillation after all the refined pyridine has come over and collecting a second fraction, the stopping point of which is determined according to the quality of heavy bases required. Heavy pyridine bases are generally sold to buyers' requirements, but sometimes they are offered by the tar distiller according to a certain distillation test.

Pyridine bases are used in the purification of anthracene (German Patent 42,053, 15th April, 1887); also in one of the processes of purifying synthetic indigo and in the manufacture of cellulose esters. Refined pyridine is employed largely in Germany for the purpose of denaturing alcohol. In the synthetic production of piperidine, a drug, the compounds of which are used in the treatment of phthisis and some gouty complaints, pure pyridine is the starting-point, and pure pyridine is also employed in medicine for the treatment of asthma and some kinds of heart disease.

CHAPTER X

As mentioned in a previous chapter, large amounts of carbolic and cresylic acids are recovered from middle or carbolic oil. These acids are known collectively as tar acids, and they are removed from the oil by agitating (washing) with various strengths of caustic soda lye. The agitation is carried out in a large wrought iron vessel which is generally cylindrical in shape, and it is erected above ground in a vertical or horizontal position. It is provided with a manhole and lid, inlet pipes for the oil and the caustic soda lye, a closed steam coil arranged along the bottom, a mechanically-driven agitator, and an outlet or run-off pipe and tap. The object of the closed steam coil is to provide the plantman with a means to warm up the oil under treatment to a temperature above that at which naphthalene will deposit. Close to the outlet pipe of the washer a small separating apparatus is erected, the purpose of which is to separate any oil which may come away with the carbolate.

In some works the middle oil is washed once with a fairly weak caustic soda lye and then submitted to distillation in a fire-heated still. The distillate which is collected is then washed several times with one or two strengths of caustic soda lye to remove more tar acids. By the distillation a good deal of the surplus naphthalene is removed from the oil and remains in the bottoms left in the still. In other tar distilleries the washing process is continuous, there being no distilling operation between the first and second washings.

The well settled oil is run into the washer and warmed up to a temperature given to the carbolic plantman by the works chemist or works manager. When this temperature is reached, caustic soda lye of a predetermined strength is pumped into the washer through the supply pipe, and while it is running in the mechanical agitator is kept revolving slowly. After all the lye has been added the agitation is continued for a short time, and then the contents of the washer allowed to rest, when the oil will rise to the surface, and the caustic soda lye, now containing some tar acids, settles to the bottom. This bottom layer is known as carbolate or phenolate, and the tar acids which are contained in this are actually in chemical combination with the caustic soda. (See Chapter V, page 49.) The carbolate is run carefully from the washer, through a separator, into the carbolate storage tank. As already explained, the object of running through a separator is to prevent any oil which may come with the carbolate from reaching the storage tank; if oil gets into the carbolate it is liable to cause mischief in another part of the tar acid recovery process.

If it should be decided to distil the once-washed middle oil, it is run out of the washer into the still, but care is taken that no carbolate gets into the still with the oil, for if it does, it will hinder very much the earlier part of the distilling operation. How much distillate is collected off this oil is determined by a test made in the chemical laboratory, and as a rule, not more than one distillate is collected. The material which remains in the still, known as bottoms, is generally mixed with creosote oil. The distillate is pumped into the washer and a fairly weak solution of caustic soda lye is added while the oil in the washer is being slowly agitated. Agitation is continued for a short time after the addition of the lye, as already mentioned, and then settling is allowed to take place, the carbolate run off into the same tank as the carbolate removed from the washer before the distillation. The mixed carbolate contains a large proportion of carbolic acid and for convenience is called carbolic carbolate.

A rather stronger solution of caustic soda is now added to the partly washed middle oil, which must be warm, and gentle agitation carried out, and the settling and running off proceeded with as already explained. As a rule the oil is washed two or three times before it is removed from the washer, to be used, say, for the preparation of a special creosote. The carbolates which are obtained from the last two or three washes are run into a different storage tank, and from it a little crude carbolic acid and a considerable quantity of crude cresylic acid is recovered. It is called cresylic carbolate.

In cases in which the middle oil is not distilled, it is generally given two washes with dilute caustic soda lye, and two or three washes with a rather stronger caustic soda lye; the carbolates from the first two washes being run into the carbolic carbolate tank. It should be clearly understood that the number of washes given may vary, as during the whole of the washing process samples, not only of the oil, but also of the carbolate, are taken and examined in the chemical laboratory. If the chemist who is doing this work finds that the carbolate which is being removed from the second wash, contains a very high percentage of carbolic acid, then a third wash is put on, and the carbolate obtained from this wash run to the carbolic carbolate tank.

If it is decided by the works manager to remove the entire quantity of tar acids contained in the middle oil, then the chemist has carefully to examine the oil, say, after the fourth wash has been given, and to calculate the quantity of caustic soda lye necessary for the final wash.

As carbolic acid is more valuable than cresylic acid, every endeavour is made to recover from the oil as much of the former material as possible, and advantage is taken of a very curious physico-chemical action which takes place when a carbolate which contains a large percentage of cresylic acid is agitated with an oil which contains a fairly high percentage of carbolic acid. What actually happens is this: the cresylic acid which is contained in the carbolate is thrown out of combination with the caustic soda and goes back into the oil, while the carbolic acid in the oil combines with the caustic soda set free and becomes a part of the carbolate. By this means a carbolate containing a moderate percentage of carbolic acid is made rich enough in this material to warrant its being worked up in the carbolic acid plant. Technically, this process is known as the interchange process.

Recently, processes for the continuous washing of oils for the recovery of tar acids in the form of carbolate have been put upon the market, and one of the chief is the Pepper process. Broadly speaking, the principle upon which these plants work is the same, and briefly what takes place is the following: The correct quantity of caustic soda lye required for the removal of the tar acids in a given quantity of oil is allowed to flow slowly and at a regulated rate into a mixing tube or mixing chamber. At the same time the oil to be washed is allowed to flow slowly into the same tube or chamber. In the mixing tube, or mixing chamber, the oil and caustic soda lye are brought into intimate contact and the mixture then flows slowly into a settling tank in which the carbolate falls to the bottom and the washed oil rises to the top. The oil and carbolate are removed from the tank automatically and in a slow stream to their respective storage tanks.

In order to recover the tar acids from the carbolate it is necessary to throw them out of combination with the caustic soda, and this is done by treating the diluted carbolate with sulphuric acid or with carbonic acid gas. The former method constitutes what is known as an intermittent process, and the latter a continuous process.

In the sulphuric acid process the carbolate is diluted with water and then allowed to remain at rest for some little time in order that any traces of oil which may be entangled in it can rise to the surface and be skimmed off. To the oil free diluted carbolate strong sulphuric acid (B.O.V.) is added in small quantities at a time, while the carbolate is being agitated, until there is just a slight excess of sulphuric acid. The mixing with sulphuric acid and the agitating are sometimes conducted in a lead-lined wooden or iron tank, using a hand agitator, but in other cases, it is carried out in a large wrought iron tank, often cylindrical in shape, provided with mechanically driven agitators. Whichever type is used, after sufficient acid has been added, the contents of the agitator or tank are allowed to remain at rest to enable the tar acids, which have been set free from their combination with the caustic soda, to rise to the surface. The liquid underneath the tar acids consists of a solution of sulphate of soda in very weak acid, and this is run to the drain, but in many cases before doing so it is diluted with a large quantity of water. The tar acids are removed from this acid solution of sulphate of soda either by skimming them off the surface, by the use of a syphon, or by running off the sulphate of soda solution first and then finally removing the tar acids. The latter method is one of general adoption and the quickest separation can be obtained by its use, the last few gallons or so of the sulphate of soda being run through a separator which will retain any tar acids which may come with it.

The chemical reaction which takes place when sulphuric acid is used to set free the tar acids from the carbolate is shown by the following chemical equation—

$2\,C_6H_5ONa$	+	H_2SO_4	=	$2\,C_6H_5OH$	+	Na_2SO_4
Sodium Phenate in solution in water. (One of the constituents of carbolate.)	+	Sulphuric Acid.	=	Carbolic Acid. (A tar acid.)	+	Sodium Sulphate.

To the thoughtful reader it will be clearly seen that the use of this process brings about a waste of material in that the sulphate of soda solution, which is formed by the combination of the sulphuric acid with the caustic soda of the carbolate, is run to the drain. A process which obviates this loss, but which requires a rather more complicated apparatus, is now coming into general use. It goes by the name of the CO_2 process, and carbonic acid gas is used to decompose the sodium phenate instead of sulphuric acid. The action of the CO_2 (carbonic acid gas) on the carbolate results in the tar acids being set free and in the formation of carbonate of soda. The carbonate of soda solution is not run to waste, but is converted into caustic soda in the works, and this is used again to extract tar acids from the oils. The following chemical equation shows the manner in which the tar acids are set free from the carbolate by the use of carbonic acid gas—

$2\,C_6H_5ONa$	+	H_2O	+	CO_2	=	$2\,C_6H_5OH$	+	Na_2CO_3
Sodium Phenate	+	Water	+	Carbonic acid gas.	=	Carbolic acid.	+	Carbonate of soda.

There are two types of plant in general use for the recovery of tar acids by the CO_2 process. In one of these a reaction tower is used, and in the other large boilers or tanks, known as carbonators. In the latter type the clarified carbolate is run into the carbonators until they are filled to about half their volume. Carbonic acid gas (CO_2) is then passed through the carbolate in thin streams. This is brought about by the use of perforated pipes, which are placed along the bottom of the carbonators. The carbonic acid gas is manufactured in a special furnace in which coke is burnt, and it is washed or " scrubbed " free of undesirable impurities before it is allowed to enter the carbonating boilers. In most plants of this type the carbonators are connected up in such a fashion that the gas from the furnaces has to pass through at least three lots of carbolate before it is allowed to escape into a purifier and from this piece of apparatus into the atmosphere.

Taking, for example, a plant having four carbonators, and starting with them all containing a charge of fresh carbolate, this is what goes on: the gas containing the CO_2 passes first into No. 1 carbonator, and on leaving this into No. 2 and then into No. 3, from which it is led into the purifier and then away to the atmosphere. As soon as the chemist in charge finds that the carbolate in No. 1 is decomposed, the gas from the furnace is cut off from this carbonator and diverted into No. 2, from which it passes into No. 3, then into No. 4, and then via the purifier to the atmosphere. Meanwhile No. 1 carbonator is emptied and recharged with fresh carbolate. When the carbolate in No. 2 is decomposed the gas is shut off and passed as follows: No. 3 to No. 4 and then to No. 1; while No. 2 carbonator is being emptied and recharged. From this description the reader will see clearly that as long as there is sufficient carbolate to work up the process is continuous.

In order to find the point at which the decomposition has gone as far as it is possible to get it with carbonic acid gas, occasional tests are made in the chemical laboratory. When this point is arrived at the decomposed carbolate is pumped into a large settling tank and allowed to remain at rest for some time so that the tar acids can rise to the surface. The under-layer, which consists of an impure solution of carbonate of soda, and which is called "spent liquor," is carefully run away from the tar acids, after which these are removed into another tank. This tank is lead-lined, and it is used for finishing the tar acids by adding a little sulphuric acid to them in order to decompose any traces of entangled carbolate which have not been acted upon by the carbonic acid gas. Settling is allowed to take place after the requisite amount of sulphuric acid has been added and well mixed in, and the tar acids which rise to the surface are carefully removed and placed into a storage tank. A sample of these tar acids is removed by the chemist and tested to find out the crystallizing point, and they are either sold on the crystallizing point found or mixed with other tar acids to yield a product possessing a crystallizing point specified by the buyer.

The spent liquor, which is removed from under the tar acids in the settling tank, is examined to see if any more tar acids have risen to the surface, and if this is the case, they are very carefully skimmed off and the liquor then pumped into large cylindrical tanks, which are generally placed in a vertical position and which are fitted with mechanically-driven agitators. In these tanks, which are known as causticizers, the spent liquor is converted into caustic soda by heating up with steam, which passes through a steam coil placed at the bottom of the tank, and by the addition of lime, which is well stirred into the hot spent liquor. The chemist examines the liquor as it is being converted into caustic soda or, as it is termed, being causticized, and when he finds the process complete, agitation is stopped and the contents of the causticizer allowed to settle. During this period of rest, the excess of lime which has been added, and a large amount of carbonate of lime which has formed during the process, settles to the bottom of the causticizer. The clear liquor which remains above is very carefully syphoned off into storage tanks and the precipitate of lime, etc., called "lime slurry," is washed once or twice with water, allowed to remain at rest, and the clear liquid carefully removed and run into a separate storage tank. The first lot of liquor removed is a fairly strong solution of caustic soda, while the washings are very weak solutions of caustic soda. It is necessary to submit these weak solutions to a process of evaporation in order to concentrate them.

In many works the caustic soda solutions obtained by this process are further strengthened by the addition of some solid caustic soda, but whether this is done or not depends upon the ideas of the works management.

In the continuous process in which a reaction tower is employed, the carbolate from the storage tanks is run very slowly into a small vessel known as a sump. The sump is erected near two large cylindrical tanks, which contain the oil-free carbolate, and which are supported on brickwork cradles at a height a little above this vessel. The object of having two carbolate tanks is to allow one to be filled while the other is slowly discharging its carbolate into the sump. A small pump is fitted near the sump, and the suction pipe of this pump is so placed in it that it reaches nearly to the bottom. The delivery pipe of the pump is carried upwards to the top of a tall tower (the reaction tower), and to the end of this pipe which is inside the tower, is fitted a spraying arrangement.

The carbolate is pumped slowly to the top of the tower, and as it leaves the sprayer, falls on to what is termed "packing," which may consist of specially hard coke, earthenware balls, granite chips, or one of the many types of patent tower packings. The packing causes the carbolate to split up and run over, say, the earthenware balls, in the form of a very thin film, and naturally the time taken for the carbolate to reach the bottom of the tower is very much prolonged. During its downward passage it meets with an upward flow of gas containing a considerable quantity of carbonic acid. This gas, which enters at the bottom of the tower, is made by burning coke in a specially constructed furnace, and it is well scrubbed with water in a scrubbing tower, to relieve it of impurities, before it enters the reaction tower. The carbolate being in the form of very thin films, and flowing in a contrary direction to the gas, assists materially in the chemical reaction, which has already been explained when describing carbonating boilers, and the setting free of the tar acids from the carbolate is, if the process is carried out properly, as complete as it is possible to make it by the time it reaches the bottom of the tower.

The liquid which leaves the tower consists of a mixture of tar acids and spent liquor, and this mixture flows into a tank, which is termed technically a "divider." In this tank the spent liquor separates from the tar acids, the latter rising to the top and the former sinking to the bottom. By a special arrangement of pipes these two materials are continuously removed, the tar acids running off to a storage tank, or receiver, to await further treatment, and the spent liquor passing on to another tank from which it is pumped into causticizers, and in which it is converted into caustic soda.

The tar acids are allowed to remain at rest in the receiver for some time in order that they may precipitate out any entangled spent liquor. As a rule, there are two receivers, so that one can be emptied while the contents of the other are settling. The settled tar acids are run into a lead-lined tank and treated with a small quantity of fairly strong sulphuric acid. The acid is added gradually and is well mixed with the tar acids, and the addition of the sulphuric acid is continued until there is a slight excess present. The contents of the lead-lined tank are then allowed to remain at rest, when the tar acids will rise to the surface and an acid solution of sulphate of soda will settle to the bottom. The tar acids are carefully removed from the under liquor and pumped into a storage tank where a further settling takes place. If the carbolate is that which is rich in carbolic acid (carbolic carbolate), then the tar acids, after they have been treated with sulphuric acid and have well settled, are tested in the chemical laboratory for the water content and the crystallizing point.

There are several grades of crude carbolic acid, as these tar acids are called, and the chief of these are 45°, 50° and 60°.

If the tar acids, on testing, show a crystallizing point above or below those just named, by making a special calculation the chemist is able to instruct the plant-man how to mix the contents of one tank with those of another in order to obtain a batch of crude carbolic acid of a desired crystallizing point, say, 60°. The tar distiller sells the crude carbolic acid on the crystallizing point only, he going no further with the process of purification.

Should the carbolate be that which contains a small quantity of carbolic acid and a large quantity of the cresylic acids (cresylic carbolate), then, after the recovered tar acids have been treated with sulphuric acid and allowed to settle until quite free from acid liquor, they are pumped into a still and submitted to a process of distillation. The still is constructed of mild steel plates, and its shape is very similar to that of a tar still. On it are fixed a run-off pipe through which the bottoms are discharged, a manhole and tightly fitting lid, a safety valve, a swan-neck, through which the vapours are conducted to a small fractionating column, a hole for the return pipe from the fractionating column, and a hole for the charge pipe. The fractionating column consists of a few cast-iron segments, and upon each segment a plate or tray is cast. These plates are similar in design to those already described on page 66. Arrangements are made so that the first portion of the distillate coming off the crude cresylic acid is by-passed and does not enter the fractionating column, but runs direct to the condenser coil. On the top of the fractionating column is fitted an outlet pipe which conducts the vapours to the condensing coil.

When the still is properly charged firing is commenced, and is conducted with caution for the reason that the cresylic acid contains a certain amount of water which is given off at the commencement of the distillation, and if care is not used, priming will occur. So long as water comes with the distillate the vapours are not allowed to enter the fractionating column, but are by-passed into the condenser coil. The mixed distillate is allowed to pass through a separator which automatically removes the water from the oil. The water is run to waste, and the oil, which consists chiefly of crude carbolic acid, is led into an iron tank or receiver. Sometimes it is collected in wooden barrels. On the disappearance of the water, the by-pass is cut out and the vapours coming from the still are allowed to pass up the fractionating column. The object of doing this is to separate roughly any more crude carbolic acid which may be present in the cresylic acid undergoing distillation. The point at which the distillate is run into the distilled cresylic acid receiver has to be decided by special tests, which are made in the chemical laboratory. The crude carbolic acid collected during the distillation is mixed with the crude carbolic acid recovered by one or other of the processes already described.

The cresylic acid distillate, however, is not yet ready for sale, as it possesses a very strong odour resembling bad eggs, which is due to the presence of sulphuretted hydrogen and other sulphurous compounds. It is necessary to remove these foul-smelling substances as far as possible, and to attain this object the distilled acid is pumped from the receiver into a large iron tank, and is there submitted to an air-blowing process. Air is pumped into the tank by an air pump and passes through a perforated coil, which is laid upon the bottom of the tank. As the air rises through the cresylic acid in the form of fine bubbles it picks up and carries with it the sulphuretted hydrogen, and on leaving the acid it enters a pipe which is attached to the top of the air-blowing tank, and is led by this pipe into a purifying apparatus, or else is burned under the steam boilers. The end of the air-blowing process is determined by chemical tests carried out in the laboratory.

Crude cresylic acid is placed on the market in several qualities, and it is generally valued on its content of tar acids; a quality frequently demanded is one which is sweet smelling and contains about 98 per cent. of tar acids.

Purified cresylic acid, when treated with strong sulphuric acid, forms a substance called a sulphonate, and the sodium salt of this material enters into the composition of some blasting powders and safety explosives. A product of cresylic acid called ammonium mono nitro cresol sulphonate is also used in the production of some German explosives. If meta cresol, one of the three cresols of which crude cresol is composed, is acted upon by nitric acid in the presence of strong sulphuric acid a substance which goes by the name of tri-nitro meta cresol (or cresylite) is formed. Cresylite enters into the composition of some of the high explosives.

In the manufacture of certain types of disinfectants cresylic acid is used in considerable quantities. For instance, lysol is prepared by mixing about 50 per cent. of cresylic acid with about 50 per cent. of a specially made soft soap.

The various grades of crude carbolic acids occur in the form of liquids and they are sold to the manufacturer of commercially pure and chemically pure carbolic acids. Both of these materials occur in the form of crystals. Commercially the value of carbolic acid is very considerable, as it is the starting-point in the manufacture of many coal tar colours, artificial drugs, artificial perfumes, and some explosives.

In the sciences of medicine and surgery pure carbolic acid is used fairly extensively. Made up in the form of a lotion it is employed largely in the treatment of wounds in war, and it is administered in the form of pills in the treatment of typhoid fever. It is employed in the manufacture of a large number of pharmaceutical preparations, and some toilet requisites such as tooth powder.

Many artificial drugs have their source in phenol. For instance, the well-known antipyretic and antirheumatic aspirin is prepared as follows: *Phenol* (carbolic acid) is treated with caustic soda and the resulting product submitted to the action of dry carbonic acid gas under pressure and at a temperature of about 130° C. The *sodium salicylate* which is formed is dissolved in water, and the solution treated with hydrochloric acid, which sets free the *salicylic acid*. This is dried and then heated with acetic anhydride or acetyl chloride when acetylsalicylic acid or *aspirin* results. Among the other artificial drugs prepared from phenol may be mentioned sodium salicylate, salol and phenacetin.

In the explosives industry *phenol* finds extensive use particularly in the manufacture of *picric acid*. This acid is prepared by treating carbolic acid first with concentrated sulphuric acid, and then with concentrated nitric acid. Its scientific name is trinitrophenol, and it is used as a shell filler under the name of Melinite in France, Lyddite in England, Granatfullung 88 in Germany, and Pertite in Italy. It should be noted that there is a tendency to replace picric acid by trinitrotoluene for special reasons which cannot be discussed in this work.

The perfume industry is indebted to carbolic acid for at least two artificial perfumes, viz., *artificial wintergreen oil* (*methyl salicylate*), and a crystalline substance known as *coumarine*, which possesses an odour resembling that of new mown hay.

Carbolic acid is the raw material from which many coal tar colours are prepared, and reference to the " family tree" (Fig. 17), which is by no means complete.

will give the reader some idea of its value in this connection.

The production of carbolic acid varies from year to year, but the amount is considerable. An average annual figure for crude carbolic acid manufactured in the United Kingdom is 6,348,000 gallons.

BIBLIOGRAPHY

To the reader whose appetite has been whetted for further information on the subject of Coal Tar and its products the writer recommends a study of the following works—

Coal Tar and Ammonia. By George Lunge. Fifth Edition, £3 3s. net. Publishers: Gurney & Jackson, 1 Paternoster Row, London, E.C.

A large treatise of three volumes, which deals with the methods used in various parts of the world for distilling coal tar and purifying many of the distillation products, and also with the working up of ammonia and the manufacture of compounds of ammonia. It contains a full account of the properties of the substances which occur naturally in coal tar, or which are obtained from it, by destructive distillation.

Coal Tar Distillation. By Arthur R. Warnes. Third Edition, 45s. net Publishers: Benn Bros., Ltd., 8 Bouverie Street, London, E.C.4.

A work of one volume, which treats of the constitution of coal, the constitution and properties of coal tar, and the methods of coal tar distillation and the working up of tar products as employed in Great Britain. The chemical engineering as well as the techno-chemical side are dealt with fully. This book contains a chapter on the methods of obtaining benzol and toluol from coal gas (gas stripping) and also a comprehensive chapter on tarworks tests.

The Carbonization of Coal. By Vivian Byam Lewes. Second Edition, 12s. 6d. net. Publishers: Benn Bros., Ltd., 8 Bouverie Street, London, E.C.4.

This book deals exhaustively with the formation, composition and destructive distillation of coal for gas, coke and by-products. There is an excellent chapter on "Tar: Its Formation, Use and Decomposition."

The Treasures of Coal Tar. By Alexander Findlay. First Edition. 4s. 6d. net. Publishers: George Allen & Unwin, Ltd., London.

A book written with the object of promoting scientific knowledge amongst the people, particularly the merchant, banker and lawyer.

By-Product Coking. By G. Stanley Cooper. First Edition. 7s. 6d. net. Publishers: Benn Bros., Ltd., 8 Bouverie Street, London, E.C.4.

This work deals with the methods and plant used to produce special coke for metallurgical purposes, and with the recovery of the by-products coal tar, ammonia, and benzol. In this book there are chapters on " The Recovery of Tar and Ammonia," " The Recovery of Benzol " and " Tar Distillation."

Modern Coking Practice. By J. E. Christopher & T .H. Byron. Second Edition. Vol. II. 7s. 6d. net.

This volume treats of the recovery of by-products from modern coke ovens. It contains chapters dealing with the direct and semi-direct processes of ammonia recovery, the distillation of tar and the recovery of benzol from gas.

The Manufacture of Sulphate of Ammonia. By G. T. Calvert. Second Edition. 7s. 6d. net. Publishers: Benn Bros., Ltd., 8 Bouverie Street, London, E.C.4.

A very practical work dealing with the plant and processes used in the recovery of ammonia from ammonical liquor and its conversion into sulphate of ammonia.

Dyestuffs and Coal Tar Products. Edited by Geoffrey Martin. First Edition. 7s. 6d. net. Publishers: Crosby Lockwood & Son, Ludgate Hill, London, E.C.4.

A techno-chemical monograph briefly dealing with the subjects of coal tar and coal tar products, synthetic colouring matters, saccharine, synthetic drugs and photographic chemicals.

The Chemistry of Synthetic Drugs. By Percy May. Second Edition. 10s. 6d. net. Publishers: Longmans, Green & Co., Paternoster Row, London.

An excellent little work, strictly scientific, dealing with many of the synthetic drugs which have their origin in the products of coal tar.

INDEX

ACETANILIDE, 78
Acid tar, 61
Alizarin, xviii (Introduction)
Ammonia water, 39
—— still, 40
Ammoniacal liquor, 12, 39
Ammonium bromide, 47
—— carbonate, 39, 47
—— chloride, 39 47
—— cyanide, 39
—— fluoride, 47
—— hydrate, 47
—— hydrosulphide, 39
—— nitrate, 47
—— phosphate, 47
—— sulphate, 39, 44
—— sulphide, 39
—— sulphite, 39
—— sulphocyanide, 39
—— vanadate, 47
Aniline, 78
—— colours, 38
Anthracene dyes, 38
—— oil, 17, 34
—— sludge, 36
Antifebrin, 78
Anti-corrosive paints, 72
Antipyrine, 78
Aspirin, 100
Atoxyl, 78
Azo-colours, 79

BENZALDEHYDE, 80
Benzene in crude naphtha, 50
——, preparation of commercially pure, 75
Benzidine, 78
Benzol, once-run, 55
—— 90^s, 68, 72
—— 50^s/90^s, 68, 72
—— as motor fuel, 73
Benzyl chloride, 79
—— violet, 79
Bethell process, 26
Blue bricks, 38
Bottoms, 52, 55, 59
Boulton & Watt, x
—— process, 26
B.O.V., 61
Briquettes, 23
British Thermal Unit, 27
B.Th.U., 27

CALVERT, xx
Carbolates, 49
Carbolic acid, 86, 99
—— oil, 16, 86–88
Carbon black, 32
—— disulphide, 50
Carbonizing coal, 4
Celluloid, 32
Centrifugal machine, 28
Coal gas, 2
—— tar, properties of, 4
Colman process, 26
Common mains, 14
CO_2 process, 91
Continuous process of tar distillation, 20
Coumarin, 100
Creosote, 17, 25
Creosoting process, 26
Cresylic acid, 86. 98
Crude naphtha, 12, 48
Cyanine, xvii

DEPHLEGMATOR, 65
Destructive distillation, 4
Diazobenzene chloride, 78
Disinfectants, 27, 32
Distillates, yield of, from coal tar, 7

Distillation of coal tar, 7, 9, *et seq.*
—— of ammoniacal liquor, 39–44
—— of crude naphtha, 50, 53–55
—— of light oil, 55
—— of once-run benzol, 65–72
—— of once-run naphtha, 65–72
—— of once-run heavy naphtha, 65–72
Divider, 49, 95
D.O.V., 61

ESSENTIAL oil of almonds, artificial, 80
Exalgin, 78
Explosives, flameless, 79

FILTER-PRESS, 36, 37
Fractionating still, 51, 67
—— column, 53, 65, 66
Fuel oil, 26

GARDEN, xi
Getting Pitch, 18, 20
Grades of benzol, 68, 72
—— of naphtha, 71, 72

HEAVY naphtha, 71, 72
—— pyridine bases, 82, 85
Hird's process of tar distillation, 20–22
Hofmann, xii, xiv, xvii
Hydrocarbons, paraffinoid, 4

INDIGO (artificial), 30, 80
Interchange process (carbolic acid recovery), 89
Intermittent process of tar distillation, 9

LIGHT oil, 16
Lime, treatment of ammoniacal liquor with, 39
—— slurry, 94
Lowe, xx
Lowry process, 26
Lysol, 99

MALACHITE green, 80
Mansfield, xii, xviii, 3
Mauve, xiii
Mesitylene, 50
Methyl aniline, 78
Middle oil, 86, 87, 88
Motor fuel, 73

NAPHTHA, crude, 12, 48
—, distillation of, 50
—, 71
solvent, 71, 72
Naphthalene, 4, 28
—— dyes, 30
—— as disinfectant, 32
—— as fuel, 32
Nitrobenzene, 78

OBSERVATION box, 12
Once-distilled light oil, 55
Once-run benzol, 55
—— heavy naphtha, 59
—— naphtha, 59

PARAFFINOID hydrocarbons, 4
Patent fuel, 23
Pepper process, 89
Perkin, W. H., xiii, xv, xvi xvii, xviii
——, F. M., xiv
Phenates, 49
Phenol, 49, 100
—— and caustic soda, 49
Phenylhydrazine, 78
Picric acid, 100
Pitch, 18, 23
—— bay, 18,
—— coolers, 18, 20
Preheater, 42
Priming, 56
Producer gas, 10
Pyridine, 62, 81
—— acid, 81

Pyridine, bases, 60
—— sulphate, 62

RECEIVERS, 14
Retorts, 1
Road-making, pitch-grouted macadam tor, 24
Roofing felt, 6
Rueping process, 26

SACCHARINE, 80
Salicylic acid, 100
Savery, Capt. Thomas, ix
Saturator, 42
Separator, 49, 95
Sheep dips, 27
Sodium salicylate, 100
Spent liquor, 42, 93
Still, tar, 9 *et seq.*, 20
—— ammonia, 40–42, 43
—— benzol and naphtha, 52, 53, 65, 66
—— fractionating, 51–53, 65, 66
Strained oil, 38
Sublimation, 30
Sulphate of ammonia plant, 41

TAR still, 9 *et seq.*, 20
—— well, 1
Thiophene, 75
T.N.T., 79
Toluene in crude naphtha, 50
Toluol, 69, 76
Trinitrophenol, 100
Trinitrotoluene, 79

VIRGIN light oil, 55

WASHER, 48, 60
Water tank or condenser tank, 12
Watt, James, x
Williams, Greville, xvii
Wintergreen oil, 100

XYLENE, ortho, 50
——, meta, 50
——, para, 50
Xylenes, 5, 50, 52
——, commercially pure, 77

PRINTED IN GREAT BRITAIN AT THE PITMAN PRESS, BATH
C—(1468B)

A SELECTION FROM THE LIST OF

COMMERCIAL HANDBOOKS

PUBLISHED BY

SIR ISAAC PITMAN & SONS, LTD.

The following Catalogues will be sent post free on application: COMMERCIAL, EDUCATIONAL, TECHNICAL, SHORTHAND, FOREIGN LANGUAGES, and ART.

Obtainable through any Bookseller or direct from the Publishers

LONDON: PARKER STREET, KINGSWAY, W.C.2
BATH: The Pitman Press. MELBOURNE: The Rialto, Collins Street.
NEW YORK: 2 West 45th Street. TORONTO: 70 Bond Street.
INDIA: A. H. Wheeler & Co., Hornby Road, Bombay; 11 Clive Street, Calcutta; and 15 Elgin Road, Allahabad.

The Prices contained in this List apply only to Great Britain.

CONTENTS

PAGE
ADVERTISING AND COMMERCIAL ART . 21
ARITHMETIC, ETC. . . . 2
BANKING AND FINANCE 11–12
BOOK-KEEPING AND ACCOUNTANCY 3–5
BUSINESS ORGANIZATION AND MANAGEMENT 18-19
CAREERS, ETC. 6
CIVIL SERVICE . . . 6
COMMERCE, ETC.. . . . 7
COMMON COMMODITIES AND INDUSTRIES . . 31–32
ECONOMICS. 10
ENGLISH AND COMMERCIAL CORRESPONDENCE . . 8
PAGE
FOREIGN LANGUAGES . 28–29
GEOGRAPHY AND HISTORY . 9
INCOME TAX . . 15
INDUSTRIAL ADMINISTRATION 17–18
INSURANCE . . 13–14
LAW . . . 24–25
MUNICIPAL WORK . . 20
REFERENCE BOOKS . 26–27
SALESMANSHIP . . 22
SECRETARIAL WORK . . 16
SHIPPING 15
SHORTHAND . . . 29
TRANSPORT . . . 23
TYPEWRITING . . . 30

A SELECTION FROM THE LIST OF

COMMERCIAL HANDBOOKS

PUBLISHED BY

SIR ISAAC PITMAN & SONS, LTD.

The following Catalogues will be sent post free on application: COMMERCIAL, EDUCATIONAL, TECHNICAL, SHORTHAND, FOREIGN LANGUAGES, and ART.

Obtainable through any Bookseller or direct from the Publishers

LONDON: PARKER STREET, KINGSWAY, W.C.2
BATH: The Pitman Press. MELBOURNE: The Rialto, Collins Street.
NEW YORK: 2 West 45th Street. TORONTO: 70 Bond Street.
INDIA: A. H. Wheeler & Co., Hornby Road, Bombay; 11 Clive Street, Calcutta; and 15 Elgin Road, Allahabad.

The Prices contained in this List apply only to Great Britain.

CONTENTS

PAGE
ADVERTISING AND COMMERCIAL ART 21
ARITHMETIC, ETC. . . . 2
BANKING AND FINANCE 11–12
BOOK-KEEPING AND ACCOUNTANCY 3–5
BUSINESS ORGANIZATION AND MANAGEMENT . . 18-19
CAREERS, ETC. 6
CIVIL SERVICE 6
COMMERCE, ETC.. . . . 7
COMMON COMMODITIES AND INDUSTRIES . . 31–32
ECONOMICS. 10
ENGLISH AND COMMERCIAL CORRESPONDENCE . . 8
FOREIGN LANGUAGES . 28–29
GEOGRAPHY AND HISTORY . 9
INCOME TAX 15
INDUSTRIAL ADMINISTRATION 17–18
INSURANCE. . . 13–14
LAW 24–25
MUNICIPAL WORK . . 20
REFERENCE BOOKS . 26–27
SALESMANSHIP . . . 22
SECRETARIAL WORK . . 16
SHIPPING 15
SHORTHAND 29
TRANSPORT 23
TYPEWRITING 30

ARITHMETIC, ETC.

		PRICE
Arithmetic and Book-keeping		
By Thos. Brown, F.S.S., and Vincent E. Collinge, A.C.I.S. In two parts. Part I	Net	2/6
Part II	Net	1/3
Arithmetic Class Book		
By W. R. Barham		2/6
Arithmetic of Commerce		
By P. W. Norris, M.A., B.Sc. (Hons.)	Net	4/-
Business Calculations		
By F. Heelis, F.C.I.S.		2/-
Commercial Invoicing		
By Max M. Kay	Net	1/6
Commercial Mathematics		
By L. H. L. Davies, B.A., and E. G. H. Habakkuk		5/-
Complete Commercial Arithmetic		3/-
Answers	Net	1/6
Complete Mercantile Arithmetic		
By H. P. Green, F.C.Sp.T. (With Key)	Net	6/-
Counting-House Mathematics		
By H. W. Porritt and W. Nicklin, A.S.A.A.	Net	2/-
Elements of Commercial Arithmetic		
By Thomas Brown	Net	2/-
Logarithms Simplified		
By Ernest Card, B.Sc., and A. C. Parkinson, A.C.P.	Net	2/6
Principles and Practice of Commercial Arithmetic		
By P. W. Norris, M.A., B.Sc.	Net	7/6
Rapid Methods in Arithmetic		
By John Johnston. Revised and Edited by G. K. Bucknall, A.C.I.S.	Net	1/-
Slide Rule Applied to Commercial Calculations, The		
By R. M. Shireby	Net	2/6
Smaller Commercial Arithmetic		
By C. W. Crook, B.A., B.Sc.	Net	2/-

BOOK-KEEPING AND ACCOUNTANCY

			PRICE
Accountancy	By F. W. Pixley, F.C.A., *Barrister-at-Law*	Net	7/6
Accountants' Dictionary	Edited by F. W. Pixley, F.C.A. In 2 Vols.	Net	63/-
Accounting	By S. S. Dawson, M.Com., F.C.A., and R. C. de Zouche, F.C.A.	Net	10/6
Accounts of Executors, Administrators, and Trustees	By William B. Phillips, F.C.A., A.C.I.S.	Net	5/-
Advanced Accounts	Edited by Roger N. Carter, M.Com., F.C.A.	Net	7/6
Key to Advanced Accounts	By R. A. Goodman		20/-
Advanced Book-keeping Exercises for Commercial Schools	By A. J. Favell, B.Sc.(Econ.), A.C.I.S.		2/6
Apportionment in Relation to Trust Accounts	By A. F. Chick, *Incorporated Accountant*	Net	6/-
Auditing, Accounting, and Banking	By F. Dowler, A.C.A., and E. M. Harris, A.I.B.	Net	7/6
Auditors : Their Duties and Responsibilities	By F. W. Pixley, F.C.A.	Net	21/-
Audit Programmes	By E. E. Spicer, F.C.A., and E. C. Pegler, F.C.A.	Net	4/6
Balance Sheets, Business	By F. R. Stead	Net	10/6
Book-keeper's Vade Mecum, The	By S. Howard Withey, F.C.I., A.L.A.A.	Net	3/6
Book-keeping, A Course in	By R. W. Holland, O.B.E., M.A., M.Sc., LL.D.	Net	4/-
Book-keeping and Accounts	By E. E. Spicer, F.C.A., and E. C. Pegler, F.C.A.	Net	20/-
Book-keeping and Office Work	By R. J. Porters, F.C.R.A. Two Vols.	Net	30/-
Book-keeping for Beginners	By W. E. Hooper, A.C.I.S.	Net	2/-

Book-keeping and Accountancy—contd.

PRICE

Book-keeping for Retailers
By H. W. Porritt and W. Nicklin, A.S.A.A. . . Net 2/-

Book-keeping for Shopkeepers
By J. Greig, F.C.I. . . . . . . Net 2/6

Book-keeping, Modern Methods of
By R. H. Epps, *Chartered Accountant* . . Net 4/-

Book-keeping Teachers' Manual
By C. H. Kirton, A.C.I.S. . . . . . Net 7/6

Branch Accounts
By P. Taggart. A.S.A.A. . . . . . Net 3/-

Builders' Accounts and Costs
By Robert G. Legge . . . . . . Net 3/6

Business Book-keeping
By J. Routley . . . . Net 3/6

Commercial Goodwill
By P. D. Leake, F.C.A. . . . . . Net 21/-

Company Accounts
By Arthur Coles. Revised by W. C. Wood, A.C.I.S. . . . . Net 7/6

Consignments, Account Sales, and Accounts Current
By E. J. Hammond, A.C.I.S., A.L.A.A. . . . Net 5/-

Cost Accounting
By W. B. Lawrence, C.P.A. . . . . . Net 21/-

Cost Accounts in Principle and Practice
By A. Clifford Ridgway, F.C.A. . . . . Net 5/-

Cost Accounts for the Metal Industry
By H. E. Parkes, M.Com., A.C.W.A. . . . Net 10/6

Costing and Price Fixing
By J. M. Scott Maxwell, B.Sc., F.C.W.A. . Net 6/-

Costing, A Primer of
By R. J. H. Ryall . . . . . . Net 5/-

Costing, Dictionary of
By R. J. H. Ryall . . . . . . Net 10/6

Costing, Theory and Practice of
By E. W. Newman, F.C.A. . . . . . Net 8/6

Costs for Manufacturers
By C. Smith . . . . Net 5/-

Depreciation and Wasting Assets
By P. D. Leake, F.C.A. . . . . . Net 15/-

Dictionary of Book-keeping
By R. J. Porters, F.C.R.A. . . . . Net 7/6

Book-keeping and Accountancy—contd.

PRICE

Estimating
By T. H. Hargrave . . . . . . Net 7/6

Examination Notebook for Accountant Students, An
By E. E. Spicer, F.C.A., and E. C. Pegler, F.C.A. Net 4/6

Executorship Accounts
By C. Townsend . . . . Net 5/-

Foreign Exchange Accounting
By C. Djoröp . . . . Net 15/-

Full Course in Book-keeping
By H. W. Porritt and W. Nicklin, A.S.A.A. Net 5/-

Graded Book-keeping Exercises for Commercial Schools
By A. J. Favell, B.Sc., A.C.I.S. 2/-

Higher Book-keeping and Accounts
By H. W. Porritt and W. Nicklin, A.S.A.A. Net 5/-

Holding Companies
By A. J. Simons, A.C.A. (Hons.) . . . Net 10/6

Hotel Book-keeping . . . . . . Net 2/6

Manual of Cost Accounts
By H. Julius Lunt, F.C.A., F.C.I.S., F.C.W.A. Net 7/6

Notes of Lessons on Book-keeping
By J. Routley . . . . Net 3/6

Practical Auditing
By E. E. Spicer, F.C.A., and E. C. Pegler, F.C.A. Net 21/-

Principles of Accounts
By J. Stephenson, M.A., M.Com., D.Sc.
Part I, 3/6 . . . . Part II 5/-

Principles of Auditing
By F. R. M. De Paula, O.B.E., F.C.A. . . Net 7/6

Principles of Book-keeping Explained
By I. H. Humphrys . . . . . . Net 2/6

Questions and Answers in Book-keeping and Accounting. By F. F. Sharles, F.S.A.A. . Net 10/6

Sharles's Elementary Book-keeping
By F. F. Sharles, F.S.A.A., F.C.I.S. 3/6

Shopkeepers' Accounts Simplified
By C. D. Cornell . . . . . . Net 2/-

Sinking Funds, Reserve Funds, and Depreciation. By J. H. Burton, A.S.A.A. . . Net 3/6

CAREERS, ETC.

			PRICE
Authorship and Journalism	By Albert E. Bull	Net	3/6
Banking as a Career	By F. A. Willman, Cert. A.I.B.	Net	3/6
Game of Commerce, The	By Herbert Kendrick	Net	3/6
How to Become an Auctioneer and Estate Agent	By W. F. Nokes, F.A.T.	Net	3/6
How to Become a Company Secretary	By E. J. Hammond, A.C.I.S.	Net	3/6
How to Become a Private Secretary	By J. E. McLachlan, F.I.P.S. (Hons.)	Net	3/6
How to Become a Qualified Accountant	By R. A. Witty, F.S.A.A.	Net	3/6
How to Choose Your Career	By W. Leslie Ivey, M.C.	Net	3/6
How to Secure a Good Job	By W. Leslie Ivey, M.C.	Net	3/6

CIVIL SERVICE

Civil Service Arithmetic Tests	By P. J. Varley-Tipton	Net	2/6
Civil Service Essay Writing	By W. J. Addis, M.A.	Net	2/6
Civil Service Guide	By A. J. Lawford Jones	Net	2/6
Civil Service Practice in Précis Writing	Edited by Arthur Reynolds, M.A. (Oxon)	Net	2/6
Copying Manuscript, Orthography, Handwriting, etc.	By A. J. Lawford Jones	Net	3/6
Elementary Précis Writing	By Walter Shawcross, B.A.	Net	2/-
Guide to Indexing and Précis Writing	By W. J. Weston, M.A., B.Sc., and E. Bowker	Net	2/-
Indexing and Précis Writing	By A. J. Lawford Jones	Net	2/6

COMMERCE, ETC.

			PRICE
Commerce for Commercial and Secondary Schools	By A. J. Favell, B.Sc.(Econ.), A.C.I.S.		3/6
Commerce, Stage I	By A. James, F.F.T.Com., F.R.Econ.S.		2/6
Commercial Handwriting and Correspondence		Net	2/6
Commercial Practice	By Alfred Schofield, B.Sc. (Econ.)	Net	3/6
Elements of Commerce	By F. Heywood, A.C.I.S.	Net	4/-
How to Study for Examinations	By D. Cooper		2/-
Manual of Business Training		Net	4/-
Modern Business and Its Methods	By W. Campbell, *Chartered Secretary*	Net	7/6
Popular Guide to Journalism	By A. Kingston	Net	2/6
Practical Journalism and Newspaper Law	By A. Baker, M.J.I., and E. A. Cope	Net	3/6
Principles and Practice of Commerce	By James Stephenson, M.A., M.Com., D.Sc.	Net	8/6
Principles of Business	By James Stephenson, M.A., M.Com., D.Sc. Part I, Net **2/6**; Part II,	Net	3/6
Questions and Answers on Business Practice	By E. J. Hammond, A.C.I.S., A.L.A.A.	Net	5/-
Routine of Commerce	By Alfred Schofield, B.Sc.(Econ.)	Net	4/-
Short Story Writing and Free Lance Journalism	By Sydney A. Moseley	Net	7/6
Theory and Practice of Commerce	Edited by F. Heelis, F.C.I.S.	Net	7/6
Traders and Trading	By W. J. Weston, M.A., B.Sc.	Net	2/6
Wholesale and Retail Trade	By W. Campbell	Net	5/-

ENGLISH AND COMMERCIAL CORRESPONDENCE

		PRICE
Business Letters in English By W. J. Weston, M.A., B.Sc.	Net	3/6
Commerce and Correspondence By E. H. Grout, B.Sc.(Econ.)	Net	5/-
Commercial Correspondence and Commercial English	Net	3/6
Commercial Dictionary.	Net	1/6
Correspondence of Commerce, The By A. Risdon Palmer, B.Sc., B.A.	Net	4/-
Dictionary of Correct English, A By M. A. Pink, M.A.	Net	2/6
English and Commercial Correspondence By H. Nagaoka and D. Theophilus, B.A.		3/6
English Composition and Business Correspondence By J. F. Davis, D.Lit., M.A., LL.B. (Lond.)	Net	2/-
English Exercises. A Book of Homonyms By B. S. Barrett		3/6
English for Commercial Students By H. W. Houghton	Net	2/6
English Grammar and Composition By W. J. Weston, M.A., B.Sc. (Lond.)	Net	4/6
English Mercantile Correspondence	Net	3/6
Guide to Commercial Correspondence By W. J. Weston, M.A., B.Sc. (Lond.)		2/6
How to Teach Commercial English By Walter Shawcross, B.A.	Net	3/6
Manual of Commercial English By Walter Shawcross, B.A.	Net	3/6
Manual of Punctuation. By W. D. Webster		1/-
New Era Spelling Manual By H. J. Bower		2/6
Pocket English Dictionary	Net	1/6
Principles and Practice of Commercial Correspondence. By J. Stephenson, M.A., M.Com.	Net	7/6
Punctuation as a Means of Expression By A. E. Lovell, M.A.	Net	1/-
Synonyms and Antonyms, Pitman's Book of	Net	2/6

GEOGRAPHY AND HISTORY

		PRICE
Commercial Atlas of the World . .	Net	5/-
Commercial Geography of the British Empire Abroad and Foreign Countries . .	Net	3/-
Commercial Geography of the British Isles	Net	2/6
Commercial Geography of the World .	Net	4/6
Commercial History By J. R. V. Marchant, M.A., ...	Net	5/6
Economic Geography By John McFarlane, M.A., M.Com. . .	Net	10/6
Economic Geography, The Principles of By R. N. Rudmose Brown	Net	7/6
Economic Resources of the Empire Edited by T. Worswick, O.B.E., M.Sc. . .	Net	5/-
Elements of Commercial Geography By C. H. Grant, M.Sc., F.R.Met.Soc. . .	Net	2/-
Elements of Commercial History By Fred Hall, M.A., B.Com., F.C.I.S. . .	Net	2/-
Geography of Commerce, The By W. P. Rutter, M.Com.	Net	5/-
History of Commerce, The By T. G. Williams, M.A., F.R.Hist.S., F.R.Econ.S.	Net	5/-
Main Currents of Social and Industrial Change, 1870-1924 By T. G. Williams, M.A.	Net	5/-
Outlines of the Economic History of England By H. O. Meredith, M.A., M.Com. . . .	Net	7/6
Principles of Commercial History By J. Stephenson, M.A., M.Com., D.Sc. .	Net	7/6
Rise of British Commerce, The By K. G. Lewis, B.A., and N. Branton . .		3/6
Statistical Atlas of the World, A By J. Stephenson, M.A., M.Com., D.Sc. .	Net	7/6

ECONOMICS

			PRICE
Dictionary of Economic and Banking Terms	By W. J. Weston, M.A., B.Sc., and A. Crew	Net	5/-
Economics Educator	Edited by J. H. Jones, M.A. Three Vols.	Net	63/-
Economics for Business Men	By W. J. Weston, M.A., B.Sc.	Net	3/6
Economics for Everyman	By J. E. Le Rossignol	Net	5/-
Economics of Private Enterprise, The	By J. H. Jones, M.A.	Net	7/6
Economics of Instalment Trading and Hire Purchase.	By W. F. Crick	Net	5/-
Economics of the Manufacturing Business	By W. A. Stewart Jones, F.C.W.A., F.S.S.		3/6
Economics : Principles and Problems	By L. D. Edie	Net	15/-
Elements of Political Economy	By H. Hall, B.A.	Net	2/-
Exercises in Economics	By A. Plummer, M.Sc. (Econ.), M.A., LL.D.	Net	2/-
Guide to Political Economy	By F. H. Spencer, D.Sc., LL.B.	Net	3/6
Industrial Combination in England	By P. Fitzgerald, D.Sc.(Econ.)	Net	10/6
Introduction to Business Economics	By J. Stephenson, M.A., M.Com., D.Sc.		3/6
Outlines of Central Government	By John J. Clarke, M.A., F.S.S.	Net	5/-
Outlines of Industrial and Social Economics	By John J. Clarke, M.A., F.S.S., and James E. Pratt, A.C.I.S.	Net	1/6
Outlines of Local Government of the United Kingdom (and the Irish Free State)	By John J. Clarke, M.A., F.S.S.	Net	5/-
Plain Economics	By John Lee, M.A., M.Com.Sc.	Net	3/6
Road to Plenty, The	By W. T. Foster and W. Catchings	Net	3/6
Substance of Economics, The	By H. A. Silverman, B.A. (Econ.)	Net	6/-

BANKING AND FINANCE

PRICE

Answers to Questions Set at the Examinations of the Institute of Bankers.

By L. L. M. Minty, Ph.D., B.Sc., Econ., B.Com.—
Foreign Exchange. Part I & Part II Each Net 3/6
Economics. Part I & Part II . . Each Net 5/-
English Grammar and Composition. Part I Net 3/6
„ „ „ „ Part II . Net 5/-

Banker as a Lender, The
By F. E. Steele . . . . Net 5/-

Bankers' Advances
By F. R. Stead. Edited by Sir John Paget, K.C. Net 6/-

Bankers' Advances Against Produce
By A. Williams, A.I.B. . . . . . Net 6/-

Bankers and the Property Statutes of 1925 and 1926. By R. W Jones . . . Net 6/-

Bankers' Credits
By W. F. Spalding . . . . . . Net 10/6

Bankers' Securities Against Advances
By Lawrence A. Fogg, Cert. A.I.B. . . . Net 6/-

Bankers' Clearing House, The
By P. W. Matthews . . . . . . Net 7/6

Bankers' Tests
By F. R. Stead . . . . Net 10/6

Bank Organization, Management, etc.
By J. F. Davis, M.A., D.Lit., LL.B. (Lond.) . Net 6/-

Bills of Exchange Act, 1882, The
By M. H. Megrah, B.Com. . . . . . Net 6/-

Bills of Exchange Acts, A Practical Examination of the
By C. H. Fennell . . . . . . Net 7/6

Cheques. By C. F. Hannaford . . . . Net 6/-

Dictionary of Banking
By W. Thomson and Lloyd Christian . . Net 30/-

Dictionary of Banking Terms in Three Languages, (English-French-German)
By L. Herendi . . . . Net 21/-

Dictionary of the World's Currencies and Foreign Exchanges
By W. F. Spalding . . . . Net 30/-

Eastern Exchange, Currency, and Finance
By W. F. Spalding . . . . . . Net 15/-

Banking and Finance—contd.

		PRICE
Elements of Banking By J. P. Gandy	Net	2/-
English Banking Administration, An Outline of By Joseph Sykes, B.A. (Hons.)	Net	2/6
English Banking Methods By L. L. M. Minty, Ph.D., B.Sc., B.Com.	Net	15/-
English Composition and Banking Correspondence By L. E. W. O. Fullbrook-Leggatt, M.C., B.A.	Net	5/-
Foreign Banking Systems Edited by H. Parker Willis and B. H. Beckhart	Net	21/-
Foreign Exchange and Foreign Bills in Theory and in Practice. By W. F. Spalding	Net	7/6
Foreign Exchange, A Primer of By W. F. Spalding	Net	3/6
Foreign Exchanges, Arithmetic and Practice of the. By A. G. Sugg, Cert. A.I.B.	Net	3/6
Foreign Trade, The Finance of By W. F. Spalding	Net	7/6
Functions of Money, The By W. F. Spalding	Net	7/6
How to Succeed in a Bank By F. F. Steele	Net	3/6
London Money Market, The By W. F. Spalding	Net	10/6
Money, Exchange, and Banking By H. T. Easton, A.I.B.	Net	6/-
Notes on Banking and Commercial Law By T. Lloyd Davies	Net	3/-
Practical Banking By J. F. G. Bagshaw, Cert. A.I.B.	Net	7/6
Talks on Banking to Bank Clerks By H. E. Evans	Net	2/6
Theory and Practice of Finance, The By W. Collin Brooks	Net	10/6
Title Deeds Old and New By Francis R. Stead.	Net	5/-

INSURANCE

			PRICE
Actuarial Science, The Elements of	By R. E. Underwood, M.B.E., F.I.A.	Net	5/-
Average Clauses and Fire-Loss Apportionments.	By E. H. Minnion, F.C.I.I.	Net	8/6
Building Construction, Plan Drawing, and Surveying in Relation to Fire Insurance	By D. W. Wood, M.B.E.	Net	6/-
Burglary Risks	By E. H. Grout, B.Sc., A.C.I.I.	Net	10/6
Business Man's Guide to Insurance, The	By A. Philpott	Net	3/6
Casualty Insurance	By C. J. Crobaugh, M.A., and A. E. Redding, B.S.	Net	25/-
Compound Interest, Principles of	By H. H. Edwards	Net	5/-
Credit Risks, Commercial.	By G. H. Swain	Net	5/-
Dictionary of Accident Insurance	Edited by J. B. Welson, LL.M., F.C.I.I., F.C.I.S.	Net	60/-
Fire Extinguishment and Fire Alarm Systems	By R. Northwood	Net	7/6
Fire Insurance, Common Hazards of	By W. G. Kubler Ridley, F.C.I.I.	Net	5/-
Fire Insurance, Dictionary of	Edited by B. C. Remington, F.C.I.I.	Net	30/-
Fire Insurance, Principles and Practice of	By F. Godwin	Net	5/-
Fire Insurance, The Law of	By J. Rowlatt, B.A.	Net	7/6
Fire Policy Drafting and Endorsements	By W. C. H. Darley	Net	7/9
Fire Waste.	By G. E. Keay	Net	2/6
Guide to Marine Insurance	By Henry Keate	Net	3/6
Insurance	By T. E. Young, B.A., F.I.A., F.R.A.S.	Net	10/6
Insurance Office Organization and Routine	By J. B. Welson, LL.M., F.C.I.I., F.C.I.S., and F. H. Sherriff, F.I.A.	Net	7/6
Insurance of Profits.	By A. G. Macken	Net	5/-

Insurance—contd.

	PRICE
Insurance of Public Liability Risks By S. V. Kirkpatrick, F.C.I.I. . . . . Net	5/-
Law and Practice as to Fidelity Guarantees By C. Evans and F. H. Jones . . . . Net	6/-
Law of Accident and Contingency Insurance By F. H. Jones . . . . Net	7/6
Life Assurance from Proposal to Policy By H. Hosking Taylor, F.I.A., A.C.I.I., and V. W. Tyler, F.I.A. . . . . Net	6/-
Life Assurance, Guide to By S. G. Leigh, F.I.A. . . . . . . Net	5/-
Marine Insurance of Goods, The By F. W. S. Poole . . . . . . Net	15/-
Motor Insurance. By W. F. Todd . . . Net	6/-
Pension and Superannuation Funds, Their Formation and Administration Explained By Bernard Robertson, F.I.A., and H. Samuels Net	5/-
Pension, Endowment, Life Assurance, and Other Schemes for Commercial Companies By H. Dougharty, F.C.I.I. . . . . . Net	6/-
Personal Accident, Disease, and Sickness Insurance, The Principles and Practice of By J. B. Welson, LL.M. . . . . . Net	5/-
Physiology and Anatomy By H. Gardiner, M.S., F.R.C.S. . . . . Net	10/6
Principles and Practice of Accident Insurance, The By G. E. Banfield, A.C.I.I. . . . . . Net	6/-
Principles of Insurance By J. Alfred Eke . . . . . . Net	5/-
Successful Insurance Agent, The By J. J. Bisgood, B.A., F.C.I.S., J.P. . . . Net	2/6
Talks on Insurance Law By J. A. Watson, B.Sc., LL.B. . . . . Net	3/6
Workmen's Compensation Insurance By C. E. Golding, LL.D., F.C.I.I., F.S.S. . Net	5/-

SHIPPING

			PRICE
Case and Freight Costs	By A. W. E. Crosfield	Net	2/-
Exporters' Handbook and Glossary, The	By F. M. Dudeney	Net	7/6
How to Export Goods.	By F. M. Dudeney	Net	2/-
How to Import Goods.	By J. A. Dunnage	Net	2/-
Import and Export Trade.	By A. S. Harvey	Net	21/-
Importer's Handbook, The.	By J. A. Dunnage	Net	10/6
Manual of Exporting	By J. A. Dunnage, F.S.S., F.C.I., A.M.Inst.T.	Net	10/6
Shipbroking, Introduction to	By C. D. MacMurray and M. M. Cree	Net	3/6
Shipping.	By A. Hall and F. Heywood	Net	2/-
Shipping and Shipbroking	By C. D. MacMurray and M. M. Cree	Net	15/-
Shipping Business Methods	By R. B. Paul	Net	5/-
Shipping Finance and Accounts	By R. B. Paul	Net	2/6
Shipping Office Organization, Management, and Accounts.	By Alfred Calvert	Net	6/-
Shipping Terms and Phrases	By J. A. Dunnage	Net	2/6

INCOME TAX

Income Tax and Super-Tax	By E. E. Spicer and E. C. Pegler	Net	12/6
Income Tax, Snelling's Practical	By C. W. Chivers	Net	3/6
Income Tax Relief, Double	By H. E. Seed and A. W. Rawlinson	Net	10/6
Income Tax Reliefs	By A. W. Rawlinson, A.C.A.	Net	20/-
Income Tax, Super-Tax, and Surtax **The New Law Explained**	By V. Walton, F.C.A., F.R.S., F.R.Econ.S.	Net	7/6

SECRETARIAL WORK, ETC.

		PRICE
Chairman's Manual By Gurdon Palin, and Ernest Martin, F.C.I.S.	Net	5/-
Company Registrar's Manual, The By J. J. Quinlivan	Net	10/6
Company Secretarial Work By E. Martin, F.C.I.S.	Net	2/-
Company Secretary's Vade Mecum Edited by P. Tovey, F.C.I.S. Revised by C. W. Adams, A.C.I.S.	Net	3/6
Dictionary of Secretarial Law and Practice Edited by Philip Tovey, F.C.I.S.	Net	42/-
Examination Notes on Secretarial Practice By C. W. Adams, A.C.I.S.	Net	2/6
Formation and Management of a Private Company By F. D. Head, B.A.	Net	7/6
Guide for the Company Secretary By Arthur Coles.	Net	6/-
Guide to Company Secretarial Work By O. Oldham, A.C.I.S. Revised by G. K. Bucknell, A.C.I.S. (Hons.)	Net	3/6
Honorary Secretaryship By W. B. Thorne	Net	2/6
How to Take Minutes Edited by E. Martin, F.C.I.S.	Net	2/6
Meetings By F. D. Head, B.A.	Net	5/-
Outlines of Transfer Procedure in Connection with Stocks, Shares, etc. By F. D. Head, B.A. (Oxon), *Barrister-at-Law*	Net	3/6
Practical Share Transfer Work By F. W. Liddington	Net	3/6
Prospectuses: How to Read and Understand Them By Philip Tovey, F.C.I.S.	Net	5/-
Questions and Answers on Secretarial Practice By E. J. Hammond. Revised by G. K. Bucknell, A.C.I.S. (Hons.)	Net	7/6
Secretary's Handbook Edited by Sir H. E. Blain, C.B.E.	Net	5/-
Transfer of Stocks, Shares, and Other Marketable Securities By F. D. Head, B.A.	Net	10/6

INDUSTRIAL ADMINISTRATION

		PRICE
Dictionary of Industrial Administration	Edited by J. Lee, C.B.E., M.A., M.Com.Sc. Two Vols.	Net 63/-
Employment Management	Compiled and Edited by Daniel Bloomfield	Net 8/6
Engineering Factory Supplies	By W. J. Hiscox	Net 5/-
Factory Administration in Practice	By W. J. Hiscox	Net 8/6
Factory Lay-Out, Planning and Progress	By W. J. Hiscox	Net 7/6
Factory Organization	By C. H. Northcott, M.A., Ph.D., O. Sheldon, B.A., J. W. Wardropper, B.Sc., B.Com., A.C.W.A., and L. Urwick, M.A.	Net 7/6
Fair Wage, A	By E. Batten	Net 2/6
Industrial Conflict	By the Right Hon. George N. Barnes	Net 3/6
Industrial Control (Applied to Manufacture)	By F. M. Lawson, A.M.I.C.E., A.M.I.Mech.E.	Net 8/6
Industrial Organization	By John Lee, C.B.E., M.A., M.Com.Sc.	Net 5/-
Industrial Organization, The Evolution of	By B. F. Shields, M.A.	Net 10/6
Introduction to Industrial Administration, An	By J. Lee, C.B.E., M.A., M.Com.Sc.	Net 5/-
Lectures on Industrial Administration	Edited by B. Muscio, M.A.	Net 6/-
Letters to an Absentee Director	By John Lee, C.B.E., M.A., M.Com.Sc.	Net 5/-
Management	By J. Lee, C.B.E., M.A., M.Com.Sc.	Net 5/-
Modern Industrial Movements	Edited by D. Bloomfield	Net 10/6
New Leadership in Industry, The	By S. A. Lewisohn	Net 7/6
Outlines of Industrial Administration	By R. O. Herford, H. T. Hildage, and H. G. Jenkins	Net 6/-
Patents for Inventions	By J. E. Walker, B.A., and R. B. Foster, B.Sc.	Net 21/-

Industrial Administration—contd.

		PRICE
Philosophy of Management, The By Oliver Sheldon, B.A.	Net	10/6
Principles of Industrial Administration, An Introduction to By A. P. M. Fleming, C.B.E., M.Sc., M.I.E.E., and H. J. Brocklehurst, M.Eng., A.M.I.E.E.	Net	3/6
Principles of Industrial Welfare By J. Lee, C.B.E., M.A., M.Com.Sc.	Net	5/-
Problems of Labour Compiled and Edited by Daniel Bloomfield	Net	8/6
Research in Industry By A. P. M. Fleming, C.B.E., M.Sc., M.I.E.E., and J. G. Pearce, B.Sc., A.M.I.E.E.	Net	10/6
Sharing Profits With Employees By J. A. Bowie, M.A.	Net	10/6
Time Standardization of Workshop Operations By T. Pilkington, M.I.Mech.E.	Net	16/-
Welfare Work in Industry Edited by E. T. Kelly	Net	5/-
Workshop Committees By C. G. Renold	Net	1/-

BUSINESS ORGANIZATION AND MANAGEMENT

Business Management By Percival White	Net	15/-
Business Management for Small Retailers By H. W. Theedam	Net	3/6
Clubs and Their Management By F. W. Pixley	Net	10/6
Colliery Office Organization and Accounts By J. W. Innes, F.C.A., and T. C. Campbell, F.C.I.	Net	7/6
Commercial Management By C. L. Bolling	Net	10/6
Counting-House and Factory Organization By J. Gilmour Williamson	Net	7/6
Drapery Business Organization, Management and Accounts. By J. Ernest Bayley	Net	7/6
Filing Systems. By E. A. Cope	Net	3/6

Business Organization and Management—contd.

			PRICE
Flour Milling Industry, Organization and Management of the.	By E. L. Pearson	Net	12/6
Grocery Business Organization and Management.	By C. L. T. Beeching, O.B.E., and J. A. Smart	Net	6/–
Hire-Purchase Trading	By Cunliffe L. Bolling	Net	10/6
Hotel Organization, Management, and Accountancy	By G. De Boni, Hotel Manager, and F. F. Sharles, F.S.A.A., F.C.I.S.	Net	10/6
How to Manage a Private Hotel	By P. Hobbs	Net	3/6
How to Organize Bazaars, Concerts, Fêtes, Exhibitions, etc.	By F. Attfield Fawkes	Net	6/–
Ironmongery and Ironmongers' Accounts	By S. W. Francis	Net	3/6
Office Machines, Appliances, and Methods	By W. Desborough, F.C.I.	Net	6/–
Office Organization and Management, Including Secretarial Work	By Lawrence R. Dicksee, M.Com., F.C.A., and Sir H. E. Blain, C.B.E.	Net	7/6
Organization of a Small Business, The	By W. A. Smith	Net	2/6
Self-Organization for Business Men	By Morley Dainow, B.Sc.(Hons.), Lond.	Net	5/–
Solicitor's Office Organization, Management, and Accounts	By E. A. Cope and H. W. H. Robins	Net	6/–
Stockbroker's Office, The	By J. E. Day	Net	7/6
Stores Accounts and Stores Control	By J. H. Burton	Net	5/–

MUNICIPAL WORK

		PRICE
Local Government of the United Kingdom, and the Irish Free State The By J. J. Clarke, M.A., F.S.S.	Net	12/6
Municipal Accounting Systems By S. Whitehead, A.S.A.A., A.C.I.S.	Net	5/-
Municipal Audit Programmes By the same Author	Net	3/6
Municipal Book-keeping By J. H. McCall, F.S.A.A.	Net	7/6
Municipal and Local Government Law By H. E. Smith, LL.B.	Net	10/6
Municipal Organization By M. H. Cox, LL.B.	Net	5/-
Municipal Student's Examination Notebook By S. Whitehead, A.S.A.A., A.C.I.S.	Net	7/6
Municipal Series Edited by William Bateson, A.C.A., F.S.A.A. Describes the Organization and Administration in the Various Departments of a Municipality.		
Principles of Organization By W. Bateson, A.C.A., F.S.A.A.	Net	3/6
Education Department By A. E. Ikin, B.Sc., LL.D.	Net	7/6
Electricity Undertaking By C. L. E. Stewart, M.I.E.E.	Net	6/-
Finance Department By W. Bateson, A.C.A., F.S.A.A.	Net	7/6
Gas Undertaking By E. Upton, F.S.A.A.	Net	5/-
Municipal Engineer and Surveyor's Department. By E. J. Elford	Net	10/6
Public Health Department By W. A. Leonard	Net	6/-
Rating Department By A. H. Peacock, M.A., A.S.A.A.	Net	5/-
Town Clerk's Department and the Justices' Clerk's Department By A. S. Wright and E. H. Singleton	Net	7/6
Tramways Department By S. B. N. Marsh	Net	6/-
Waterworks Department By F. J. Alban, F.S.A.A., F.I.M.T.A., A.C.I.S.	Net	10/6

ADVERTISING AND COMMERCIAL ART

		PRICE
Advertisement Lay-Out and Copy-Writing By A. J. Watkins	Net	15/-
Advertising Procedure By O. Kleppner	Net	21/-
Advertising Through the Press By N. Hunter	Net	5/-
Advertising to Women By C. A. Naether, M.A.	Net	21/-
Business Man's Guide to Advertising By A. E. Bull	Net	3/6
Craft of Silent Salesmanship By C. Maxwell Tregurtha and J. W. Frings	Net	5/-
Designs, Book of By C. J. and L. S. Strong	Net	16/-
Effective Postal Publicity By Max Rittenberg	Net	7/6
Language of Advertising, The By J. B. Opdycke	Net	15/-
Letter and Design, Studio Handbook By S. Welo	Net	12/6
Lettering, Plain and Ornamental By E. G. Fooks	Net	3/6
Modern Publicity. By A. W. Dean	Net	2/6
Practical Points in Postal Publicity By Max Rittenberg	Net	7/6
Practical Press Publicity By A. L. Culyer	Net	3/6
Show Card Writing, The Art of By L. J. and C. J. Strong	Net	16/-
Sign Painting. By F. H. Atkinson	Net	16/-
Ticket and Showcard Designing By F. A. Pearson	Net	3/6
Training in Commercial Art By V. L. Danvers	Net	21/-
Types and Type Faces Reprinted from "Modern Advertising" By C. M. Tregurtha	Net	2/6

SALESMANSHIP

		PRICE
Building Retail Sales By C. C. Knights	Net	5/-
Commercial Travelling. By A. E. Bull	Net	3/6
Craft of Silent Salesmanship By C. Maxwell Tregurtha and J. W. Frings	Net	5/-
Mail Order and Instalment Trading By A. E. Bull	Net	7/6
Mail Order Organization By P. E. Wilson	Net	3/6
Modern Sales Correspondence By D. M. Wilson	Net	5/-
Outline of Sales Management, An By C. C. Knights, *Sales Consultant*	Net	5/-
Practical Aids to Retail Selling By A. Edward Hammond	Net	7/6
Practical Salesmanship By N. C. Fowler, Junr.	Net	7/6
Principles of Retailing By N. A. Brisco, Ph.D.	Net	16/-
Psychology as a Sales Factor By A. J. Greenly	Net	10/6
Sales Management. By C. L. Bolling	Net	10/6
Salesmanship By W. A. Corbion and G. E. Grimsdale	Net	3/6
Salesmanship, Technique of By C. C. Knights	Net	5/-
Shop Fittings and Display By A. E. Hammond	Net	5/-
Successful Retailing. By E. N. Simon	Net	5/-
Training for More Sales By C. C. Knights, *Sales Consultant*	Net	5/-
Training for Travelling Salesmen By F. W. Shrubsall	Net	2/6
Window Dressing. By G. L. Timmins	Net	2/-

TRANSPORT

PRICE

Canals and Inland Waterways
By George Cadbury . . . . . . Net 7/6

Commercial Air Transport
By Lieut-Col. Ivo Edwards, C.M.G., and F. Tymms, M.C., A.F.R.Ae.S. . . . . Net 7/6

History and Economics of Transport, The
By A. W. Kirkaldy, M.A., B.Litt., M.Com., and A. D. Evans . . . . Net 16/-

How to Send Goods by Road, Rail, and Sea
By G. B. Lissenden . . . . . . Net 2/-

Industrial Traffic Management
By G. B. Lissenden . . . . . . Net 25/-

Modern Dock Operation
By D. Ross-Johnson, C.B.E., V.D., M.Inst.I. . Net 6/-

Modern Railway Operation
By D. R. Lamb, M.Inst.T. . . . . . Net 7/6

Motor Road Transport. By J. Phillimore . Net 10/6

Port Economics
By B. Cunningham, D.Sc., B.E., F.R.S.E., M.Inst.C.E. . . . . Net 6/-

Railway Electrification and Traffic Problems
By P. Burtt . . . . Net 10/6

Railway Rates: Principles and Problems
By P. Burtt, M.Inst.T. . . . . . . Net 6/-

Railway Statistics: Their Compilation and Use. By A. E. Kirkus, O.B.E., M.Inst.T. . Net 5/-

Rights and Duties of Transport Undertakings
By H. B. Davies, M.A. . . . . . . Net 5/-

Road Making and Road Using
By T. Salkield, M.Inst.C.E., M.Inst.T. . . Net 7/6

Traders' Rail Charges Up to Date
By J. W. Parker, A.M.Inst.T. . . . . Net 3/6

LAW

		PRICE
Bankruptcy, Deeds of Arrangement, etc. By W. Valentine Ball, M.A., *Barrister-at-Law*	Net	12/6
Bills, Cheques, and Notes By J. A. Slater, B.A., LL.B. (Lond.).	Net	6/-
Business Tenant, The By Edward S. Cox-Sinclair, and T. Hynes,	Net	7/6
Commercial Law of England, The By J. A. Slater, B.A., LL.B. (Lond.)	Net	3/6
Companies and Company Law By A. C. Connell, LL.B. (Lond.)	Net	6/-
Company Case Law By F. D. Head, B.A. (Oxon)	Net	7/6
Company Law By D. F. de L'Hoste Ranking, M.A., LL.D., and Ernest Evan Spicer, F.C.A.	Net	10/-
Elements of Commercial Law, The By A. H. Douglas, LL.B. (Lond.)	Net	2/-
Elementary Law. By E. A. Cope	Net	4/-
Examination Notes on Commercial Law By R. W. Holland, O.B.E., M.A., M.Sc., LL.D.	Net	2/6
Examination Notes on Company Law By R. W. Holland, O.B.E., M.A., M.Sc., LL.D.	Net	2/6
Executorship Law and Accounts By D. F. de L'Hoste Ranking, M.A., LL.D., E. E. Spicer, F.C.A., and E. C. Pegler, F.C.A.	Net	15/-
Guide to Company Law By R. W. Holland, O.B.E., M.A., M.Sc. LL.D.	Net	3/6
Guide to Railway Law By Arthur E. Chapman, M.A., LL.D. (Camb.)	Net	7/6
Introduction to Commercial Law By Norman A. Webb, B.Sc.		5/-
Law for Journalists By Charles Pilley, *Barrister-at-Law*	Net	5/-
Law for the House-Owner By A. H. Cosway	Net	2/6
Law of Carriage by Railway, The. In Great Britain and Ireland By L. R. Lipsett, M.A., LL.D., and T. J. D. Atkinson, M.A.	Net	50/-
Law of Contract, The By R. W. Holland, O.B.E., M.A., M.Sc., LL.D.	Net	5/-

Law—contd.

PRICE

Law of Master and Servant
By F. R. BATT, LL.M. . . . . . . Net 10/6

Law Relating to Building and Contracts
By W. T. CRESWELL, *Barrister-at-Law* . . . Net 12/6

Law Relating to Secret Commissions and Bribes. By ALBERT CREW, *Barrister-at-Law* . Net 10/6

Law Relating to Carriage by Land
By S. W. CLARKE, *Barrister-at-Law* . . . . Net 7/6

Legal Terms, Phrases, and Abbreviations
By E. A. COPE . . . . Net 3/-

Mercantile Law
By J. A. SLATER, B.A., LL.B. (Lond.) Fifth Edition, Revised by R. W. HOLLAND, O.B.E., M.A., M.Sc., LL.D., *of the Middle Temple* . . . . . Net 7/6

Outlines of Company Law
By F. D. HEAD, B.A. (Oxon) . . . . . Net 2/6

Partnership Law and Accounts
By R. W. HOLLAND, O.B.E., M.A., M.Sc., LL.D. Net 6/-

Principles of Marine Law
By LAWRENCE DUCKWORTH . . . . . Net 7/6

Questions and Answers on Commercial Law
By R. W. HOLLAND, O.B.E., M.A., M.Sc., LL.D. Net 5/-

Questions and Answers on Company Law
By G. WILLIAM FORTUNE, F.S.A.A., F.C.I.S. (Hons.), and D. R. MATHESON, M.A. (Hons.), A.S.A.A. (Hons.) Net 5/-

Railway Act, 1921, The
By R. P. GRIFFITHS, F.C.I., F.B.E.A., Grad.Inst.T. Net 2/6

Rights and Duties of Liquidators, Trustees, and Receivers, The
By D. F. DE L'HOSTE RANKING, M.A., LL.D., ERNEST E. SPICER, F.C.A., and ERNEST C. PEGLER, F.C.A. Net 15/-

Solicitor's Clerk's Guide. By E. A. COPE . Net 4/-

Trusts : Law, Administration, and Accounts
By C. KELLY and J. COLE-HAMILTON . . . Net 15/-

Wills, Executors, and Trustees
By R. W. HOLLAND, O.B.E., M.A., M.Sc., LL.D. Net 2/6

REFERENCE BOOKS

		PRICE
Bedrock of Modern Business, The By James Stephenson, M.A., M.Com., D.Sc.	Net	15/-
Business Building Edited by F. F. Sharles, F.S.A.A., F.C.I.S. 2 Vols.	Net	42/-
Business Cycles. The Problem and Its Setting By W. C. Mitchell	Net	30/-
Business Forecasting and Its Practical Application. By W. Wallace, M.Com. (Lond.)	Net	7/6
Business Man's Encyclopaedia and Dictionary of Commerce Edited by Frank Heywood, F.C.I.S. Two Vols.	Net	47/6
Business Man's Guide Edited by J. A. Slater, B.A., LL.B.	Net	6/-
Business Statistics By R. W. Holland, O.B.E., M.A., M.Sc., LL.D.	Net	3/6
Business Terms, Phrases, etc.	Net	3/6
Cable and Wireless Communications of the World, The By F. J. Brown, C.B., C.B.E., M.A., B.Sc.	Net	7/6
Charting, Manual of	Net	6/-
Charts and Graphs By Karl G. Karsten, B.A. (Oxon)	Net	25/-
Commercial Arbitrations By E. J. Parry, B.Sc., F.I.C., F.C.S.	Net	3/6
Commercial Commodities By F. Matthews, B.Sc., A.I.C., F.C.S.	Net	12/6
Commercial Contracts. By E. J. Parry	Net	5/-
Commercial Self-Educator Edited by R. W. Holland, O.B.E., M.A., M.Sc., LL.D. Two Vols.	Net	30/-
Commodities of Commerce By J. A. Slater, B.A., LL.B.	Net	6/-
Cotton World, The Compiled and Edited by J. A. Todd, M.A., B.L.	Net	5/-
Dictionary of the World's Commercial Products By J. A. Slater, B.A., LL.B. (Lond.)	Net	3/6
Discount, Commission, and Brokerage Tables By Ernest Heavingham	Net	1/6

Reference Books—contd.

		PRICE
Empire Consols. By J. F. Darling, C.B.E.	Net	1/-
Financial Statements, Analysis of By H. G. Guthmann, M.B.A., C.P.A.	Net	21/-
Fruit and the Fruit Trade By F. Fairford	Net	6/-
Guide to the Improvement of the Memory By the late Rev. J. H. Bacon	Net	1/6
Handbook on Wills, A. By A. H. Cosway	Net	2/6
How to Collect Accounts by Letter By C. Hanneford-Smith	Net	3/6
How to Grant Credit By Cuthbert Greig	Net	3/6
History, Law, and Practice of the Stock Exchange, The. By A. P. Poley, B.A.	Net	7/6
Investment Principles and Practices By R. E. Badger, Ph.D.	Net	21/-
Investor's Manual, The By W. W. Wall, F.S.S., F.J.I.	Net	3/6
Mercantile Terms and Abbreviations	Net	1/6
Money and the Stock and Share Markets, The By Emil Davies	Net	2/-
Money Making in Stocks and Shares By Sydney A. Moseley	Net	7/6
Public Speaking. By F. H. Kirkpatrick	Net	5/-
Public Speaking, Essentials of By W. C. DuBois, A.M., LL.B.	Net	8/6
Romance of World Trade, The By A. P. Dennis, Ph.D., LL.D.	Net	15/-
Shareholder's Manual, The By H. H. Bassett	Net	3/6
Speak in Public, How to By C. F. Carr and F. E. Stevens	Net	3/6
Statistics and Their Application to Commerce By A. L. Boddington	Net	12/6
Types of Business Enterprise By M. C. Cross, LL.B., Ph.D.	Net	21/-

FOREIGN LANGUAGES

FRENCH

Title	Author		PRICE
Progressive French Grammar	By Dr. F. A. Hedgcock, M.A., D.ès.L.	Net	5/6
Commercial French Grammar	By F. W. M. Draper, M.A., B. ès. L.	Net	2/6
French-English and English-French Commercial Dictionary	By F. W. Smith	Net	7/6
Manual of French Commercial Correspondence	By G. W. Macdonald	Net	5/-
Correct French Speech	By B. Dumville, M.A., F.C.P.		1/6

GERMAN

Title	Author		PRICE
A New German Grammar	By J. Keegan, M.A.	Net	5/-
Commercial German Grammar	By J. Bithell, M.A.	Net	3/6
A New German-English and English-German Dictionary for General Use	By F. C. Hebert and L. Hirsch	Net	15/-
German-English and English-German Commercial Dictionary	By J. Bithell, M.A.	Net	16/-
Commercial Correspondence in German.		Net	3/6

SPANISH

Title	Author		PRICE
Spanish Commercial Grammar	By C. A. Toledano	Net	4/6
Spanish-English and English-Spanish Commercial Dictionary	By G. R. Macdonald	Net	12/6
Manual of Spanish Commercial Correspondence	By G. R. Macdonald	Net	4/6

Foreign Languages—contd.

ITALIAN

		PRICE
Baretti's Italian and English Dictionary Compiled by GUGLIELMO COMELATI and J. DAVENPORT. In two volumes (Reprinted)	Net	25/-
Italian Commercial Grammar By LUIGI RICCI	Net	4/-
Italian-English and English-Italian Commercial Dictionary By G. R. MACDONALD.	Net	30/-
Mercantile Correspondence, English-Italian	Net	5/-

PORTUGUESE

Portuguese-English and English-Portuguese Commercial Dictionary By F. W. SMITH	Net	16/-
Practical Portuguese Grammar	Net	7/6
Mercantile Correspondence, English-Portuguese.	Net	3/6

PITMAN'S SHORTHAND

For Complete List of Textbooks, Phrase Books, Dictation Books, Reading Books, etc., see Pitman's "SHORTHAND AND TYPEWRITING CATALOGUE."

Pitman's Shorthand Instructor	4/6
Pitman's Shorthand Commercial Course	4/6
Pitman's Shorthand Rapid Course	4/6
Shorter Course in Pitman's Shorthand	1/-
English and Shorthand Dictionary	10/-
Shorthand Clerk's Guide By V. E. COLLINGE, A.C.I.S.	2/6
Progressive Dictator	2/6
Phonographic Phrase Book	Paper 1/6, Cloth 2/-

TYPEWRITING

			PRICE
Pitman's Commercial Typewriting	By W. and E. Walmsley		5/-
Pitman's Typewriter Manual			6/-
Business Typewriting	By F. Heelis, F.C.I.S.		2/-
Advanced Typewriting	By the same Author		3/6
Typist's Companion, The	By Maxwell Crooks, F.Inc.T.T., F.I.P.S.	Net	2/-
Touch Typewriting for Teachers	By Maxwell Crooks, F.Inc.T.T., F.I.P.S., F.C.T.S. (Inc.)	Net	7/6
Touch Typewriting Made Easy	By G. B. Wright		2/6
Practical Course in Touch Typewriting	By C. E. Smith		2/-
Dictionary of Typewriting	By H. Etheridge	Net	7/6
Questions and Answers on Typewriting and Office Procedure	By Arthur E. Morton		7/6
Royal Society of Arts Typewriting Tests	By A. E. Morton. No. 1, Elementary; No. 2, Intermediate; No. 3, Advanced. Each		2/6
Mechanical Devices of the Typewriter	By R. T. Nicholson, M.A.	Net	6/-
Modern Typewriting and Manual of Office Procedure	By A. E. Morton		5/6
Work and Management of a Copying Office, The	By G. C. Menzies	Net	10/6
Pitman's Gramophone Method of Rhythmic Typewriting	Comprises a complete set of specially arranged gramophone records for use in the Touch Typewriting Class and a series of carefully graded keyboard exercises	Net	35/-
	Exercises only	Each	1/6

Complete List post free on application.

COMMON COMMODITIES AND INDUSTRIES

Each book in crown 8vo, illustrated. **3s.** net.

In each of the handbooks in this series a particular product or industry is treated by an expert writer and practical man of business. Beginning with the life history of the plant, or other natural product, he follows its development until it becomes a commercial commodity, and so on through the various phases of its sale in the market and its purchase by the consumer.

Acids, Alkalis, and Salts. (Adlam.)

Alcohol in Commerce and Industry. (Simmonds.)

Aluminium. (Mortimer.)

Anthracite. (Summers.)

Asbestos. (Summers.)

Bookbinding Craft and Industry. (Harrison.)

Books—From the MS. to the Bookseller. (Young.)

Boot and Shoe Industry, The. (Harding.)

Bread and Bread Baking. (Stewart.)

Brushmaker, The. (Kiddier.)

Butter and Cheese. (Tisdale and Jones.)

Button Industry, The. (Jones.)

Carpets. (Brinton.)

Clays and Clay Products. (Searle.)

Clocks and Watches. (Overton.)

Clothing Industry, The. (Poole.)

Cloths and the Cloth Trade. (Hunter.)

Coal. (Wilson.)

Coal Tar. (Warnes.)

Coffee—From Grower to Consumer. (Keable.)

Cold Storage and Ice Making. (Springett.)

Concrete and Reinforced Concrete. (Twelvetrees.)

Copper—From the Ore to the Metal. (Picard.)

Cordage and Cordage Hemp and Fibres. (Woodhouse and Kilgour.)

Corn Trade, The British. (Barker.)

Cotton. (Peake.)

Cotton Spinning. (Wade.)

Cycle Industry, The. (Grew.)

Drugs in Commerce. (Humphrey.)

Dyes. (Hall.)

Electric Lamp Industry, The. (Percival.)

Electricity. (Neale.)

Engraving. (Lascelles.)

Explosives, Modern. (Levy.)

Fertilizers. (Cave.)

Film Industry, The. (Boughey.)

Fishing Industry, The. (Gibbs.)

Furniture. (Binstead.)

Furs and the Fur Trade. (Sachs.)

Gas and Gas Making. (Webber.)

Glass and Glass Making. (Marson.)

Gloves and the Glove Trade. (Ellis.)

Gold. (White.)

Gums and Resins. (Parry.)

Incandescent Lighting. (Levy.)

Ink. (Mitchell.)

Internal Combustion Engines. (Okill.)

Iron and Steel. (Hood.)

Ironfounding. (Whiteley.)

Jute Industry, The. (Woodhouse and Kilgour.)

Knitted Fabrics. (Chamberlain and Quilter.)

Lead, including Lead Pigments. (Smythe.)

Leather. (Adcock.)

Linen. (Moore.)

Locks and Lock Making. (Butter.)

Match Industry, The. (Dixon.)

Common Commodities and Industries—contd.

Meat Industry, The. (Wood.)
Motor Boats. (Strickland.)
Motor Industry, The. (Wyatt.)
Nickel. (White.)
Oil Power. (North.)
Oils. (Mitchell.)
Paints and Varnishes. (Jennings.)
Paper. (Maddox.)
Patent, Smokeless, and Semi-Smokeless Fuels. (Greene and Perkin.)
Perfumery, The Raw Materials of. (Parry.)
Photography. (Gamble.)
Platinum Metals, The. (Smith.)
Player Piano, The. (Wilson.)
Pottery. (Noke and Plant.)
Rice. (Douglas.)
Rubber. (Stevens and Stevens.)
Salt. (Calvert.)
Shipbuilding and the Shipbuilding Industry. (Mitchell.)
Silk. (Hooper.)
Silver. (White.)
Soap. (Simmons.)
Sponges. (Cresswell.)
Starch and Starch Products. (Auden.)
Stones and Quarries. (Howe.)
Straw Hats. (Inwards.)
Sugar. (Martineau.) (Revised by Eastick.)
Sulphur and Allied Products. (Auden.)
Talking Machines. (Mitchell.)
Tea. (Ibbetson.)
Telegraphy, Telephony, and Wireless. (Poole.)
Textile Bleaching. (Steven.)
Timber. (Bullock.)
Tin and the Tin Industry. (Mundey.)
Tobacco. (Tanner.) (Revised by Drew).
Velvet and the Corduroy Industry. (Cooke.)
Wall Paper. (Ward.)
Weaving. (Crankshaw.)
Wheat and Its Products. (Millar.)
Wine and the Wine Trade. (Simon.)
Wool. (Hunter.)
Worsted Industry, The. (Dumville and Kershaw.)
Zinc and Its Alloys. (Lones.)

Technical Dictionary of Engineering and Industrial Science in Seven Languages: English, French, Spanish, Italian, Portuguese, Russian, and German.

In four volumes, each in crown 4to, buckram gilt, 2230 pp. £8 8s. net, complete.

Compiled by Ernest Slater, M.I.E.E., M.I.Mech.E., in collaboration with leading Authorities.

PITMAN'S SHORTHAND

Invaluable to all Business and Professional Men

Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2

PRINTED IN GREAT BRITAIN AT THE PITMAN PRESS, BATH
(8831w)